5th International State-of-the-Art Congress

Groningen, The Netherlands, April 23-25, 2014

REHABILITATION: MOBILITY, EXERCISE & SPORTS





Rehabilitation: 'Mobility, Exercise & Sports' is the 5th edition of our International State-of-the-Art Congress. It builds on the strong and natural link between rehabilitation and human movement sciences. High standard thematic keynotes and free presentations are combined with posters and exhibition in a concise area and sociable atmosphere in the City of Talent!

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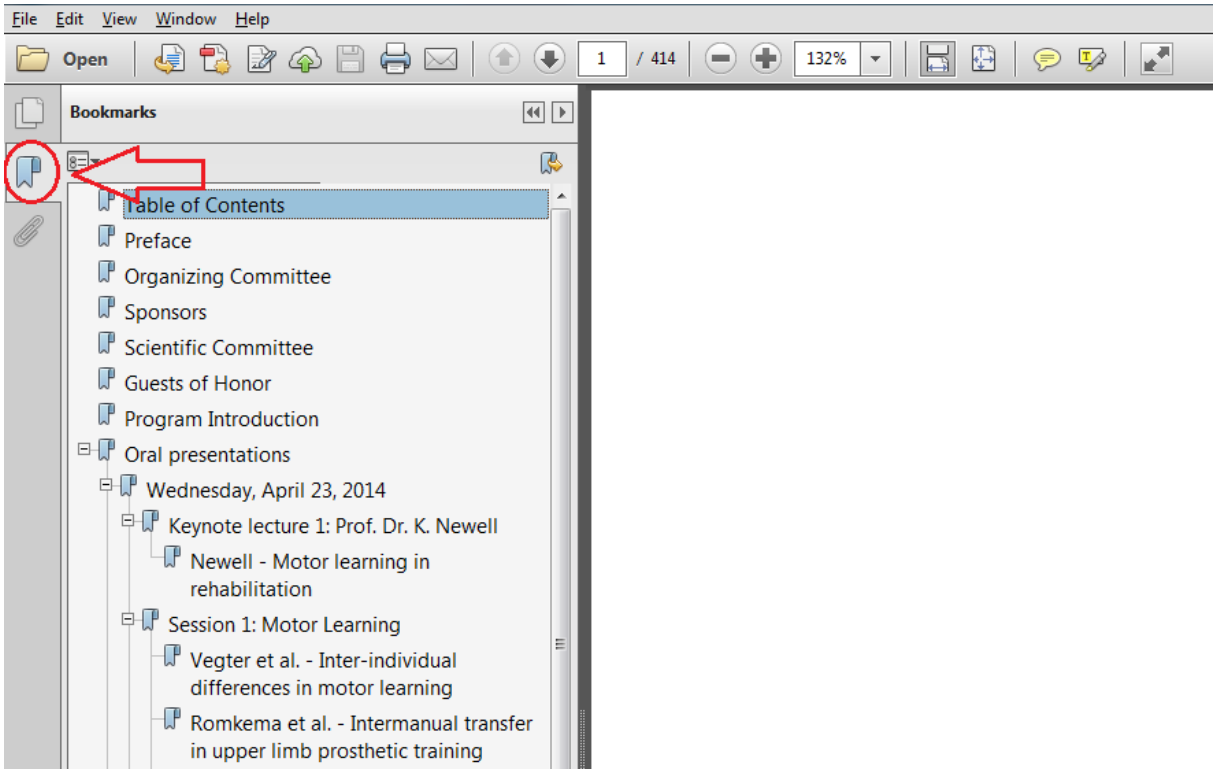

Rehabilitation: Mobility, Exercise and Sports

Proceedings of the 5th international State-of-the-Art Congress

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Preface

Groningen, February 20, 2015,

This current proceedings is the outcome of the 5th state-of-the-art congress on rehabilitation and human movement sciences in a row. This series of outcomes was generated over the past almost 25 years on basis of a congress model that started in 1990 within the framework of a European research network around wheeled mobility. The congress model and objectives stayed the same, with a small and concise group, meeting during three days, discussing the research developments in human movement and rehabilitation sciences. It now has evolved almost into some sort of tradition of each 5 years, having a congress that bridges the human movement and rehabilitation sciences and practice. It indeed exemplifies the human movement sciences and how these have evolved since the first edition. In that sense the books and journal issues describe a timeline of development and can be seen as a 'state-of –the-art' in their own right.

Personally, it has been fun, a lot of work and always a great challenge to make the ends meet, every time again. It has evolved very much into a team effort for the organizers and student assistants. In many ways it is a learningful experience for each and every one, each time. Looking back on the 5th edition, Groningen was the place to be. After 4 editions in Amsterdam at the Faculty of Human Movement Sciences of the VU University, the Centers for Human Movement and Rehabilitation Sciences of the University Medical Center Groningen and the University of Groningen were your proud hosts. The collaboration between Amsterdam and Groningen and between human movement and rehabilitation sciences proved its value. We indeed look back on a lively event, with good quality science and discussions. It was also a very social event, leading to inspiring new international connections in the historic City of Talent.

The book of extended abstracts has evolved from a hard copy edition in 1991 towards the digital open-access version of today. It will be available for all participants and hopefully it brings not only good memories, but also good and useful science for continued research as well as practical application, somewhere in near future. The proceedings will be followed by a special issue in Disability and Rehabilitation with a selection of full papers on (keynote) presentations. This special issue is planned to be published in the Summer of 2015.

I look forward to the future development of the congress; whether there will be a 6th edition of our congress is written in the stars, however.

Enjoy the book!

On behalf of the 'A-Team',

Lucas HV van der Woude

Organizing Committee

The congress was organized by the Center for Human Movement Sciences and Center for Rehabilitation of the UMCG, the Faculty of Human Movement Sciences of the VU University in Amsterdam and the Wenckebach Instituut of the UMCG.

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Program Introduction

5th State-of-the-Art Congress "Rehabilitation: Mobility, Exercise & Sports"

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Introduction

Evidence-based rehabilitation has become very important in rehabilitation practice. Therefore, at the end of the last century the Dutch Organisation for Health Research and Development (ZonMw)[i] started a research stimulation programme in the field of rehabilitation. This has led to many research programmes covering a broad array of rehabilitation strategies, among which the Dutch multi-center study 'Restoration of mobility in spinal cord injury (SCI) rehabilitation'[ii], and to fruitful collaborations among rehabilitation and academic centers. This ZonMw stimulation programme gave a boost to multi-disciplinary rehabilitation research in the Netherlands and also helped to shape the State-of-the-Art rehabilitation congress into its current form.

Before this ZonMw stimulation programme was initiated, different smaller government funds stimulated rehabilitation (technology) research. In those early days, the wheelchair studies that started in the 1980s benefitted from these funds [1, 2] and as a result the first edition of the International State-of-the-Art congress was held in 1990 within a European collaborative research framework that focused on wheeled mobility. The later editions (1998, 2004, 2009) changed slightly in content and focus, initially with stronger attention for wheeled mobility and spinal cord injury, but later addressing broader topics in human movement and rehabilitation sciences within the contexts of 'exercise = medicine' and 'healthy aging with a disability'. While the focus in terms of topics was expanded over time, the approach and objective remained the same: a congress on the cutting edge of scientific research developments with focus on mobility restoration and functional recovery in disability, and on understanding and development of theory as well as the practical connotation and implementation in rehabilitation practice and adapted sports. Each of these four congress editions were productive in their own way: publications in books [3-5] and in special issues of scientific rehabilitation journals [6, 7] as well as a growing network of collaborations among human movement sciences, rehabilitation sciences, and various research

groups, both nationally and internationally. Beyond that, there has been an important continued exchange with industry of intervention and assessment tools as well as clinical technologies.

Rehabilitation: Mobility, Exercise and Sports

The theme of the 5th State-of-the-Art congress 'Rehabilitation: Mobility, Exercise and Sports' resulted from the strong collaboration among human movement and rehabilitation sciences and professionals. Human movement sciences have been linked to rehabilitation from the start of the academic discipline, which in the Netherlands was in the early seventies. In the Netherlands, the professional training of paramedical staff is beyond the university training program. Physical and occupational therapists, but also physical education teachers are trained in a separate system of professional higher education, which today are called 'applied universities'. Human movement scientists follow a research-oriented university-based programme with a fundamental and applied connotation and with diverse subjects such as (exercise) physiology, psychology, motor control, and biomechanics. Within the context of health, rehabilitation has been an important field of research within human movement sciences. As a result, human movement sciences have actively contributed to the more evidence-based rehabilitation programmes in the Netherlands, again with help of government-funded research stimulation programmes such as ZonMw. The three guests of honour of the 5th State-of-the-Art congress, professors Willem Eisma, Rients Rozendal and Piet Rispens, have been among the founding fathers of human movement sciences in the Netherlands and were at the forefront of the active and strong collaboration of human movement and rehabilitation sciences in the Netherlands. This collaboration is nowadays visible not only in strong and productive collaboration between rehabilitation and academic centers, but also in the working groups 'Rehabilitation' of the Dutch Society of Human Movement Sciences (VvBN)[iii] and 'Human Movement & Sports' of the Dutch Association of Physical Medicine and Rehabilitation (VRA)[iv].

Similar as is seen for the general population, an active lifestyle and physical exercise are considered crucial to people with a disability both for fruitful functioning and participation in society as for long-term health reasons. To be able to be active, the first step is to have sufficient neuromuscular and cardiovascular functions and (when needed: technology-supported) mobility. This requires adequate training strategies to restore motor function through restitution or substitution and/or providing adequate assistive devices, such as orthoses, prostheses and wheelchairs. People with disabilities, however, are confronted with the paradox that while an active lifestyle requires a given level of mobility, a given level of physical fitness, which depends on an active lifestyle, is required to improve mobility. This circular dependency (figure 1) is a key issue to be solved in rehabilitation. How can we shape the rehabilitation process and the daily life condition such that this circle can be turned in the right way? Positive efforts have been made for instance with the introduction of handcycles that improve mobility and allow people to adopt an active lifestyle, which enhances fitness and subsequently activity and participation levels [8]. Moreover, many efforts have been made to extend these activities to recreational and competitive sports[v], which, next to many other purposes, contribute to improvement of mobility, fitness, health and participation (e.g. work) of people with disabilities.

The positive effects of an active lifestyle on among other things health, participation and quality of life, have been described earlier and will be subject for future studies. However, there are several issues that need attention when stimulating an active lifestyle. Besides the mobility issues, also personal and disability characteristics are important to take into account as well as the environment (social support but also whether the living environment is rural or hilly). Another important aspect in the development and treatment of an inactive lifestyle is self-management, which is, following the definition of Barlow [9] "the individual's ability to manage the symptoms, treatment, physical and psychosocial consequences and lifestyle changes inherent in living with a

disability. A dynamic and continuous process of self-regulation is established, with individuals working in partnership with relevant health professionals".

The International Classification of Functioning, Disability and Health (ICF) is very helpful in organizing the multidisciplinary treatment protocols as well as multidimensional research agenda in rehabilitation care [10]. With the ICF model at the background, the association among and importance of the congress themes Mobility, Exercise and Sports in the context of rehabilitation are visualised in figure 1. Below the themes Mobility, Exercise and Sports are further discussed in light of recent developments and the key issues presented at the current congress.

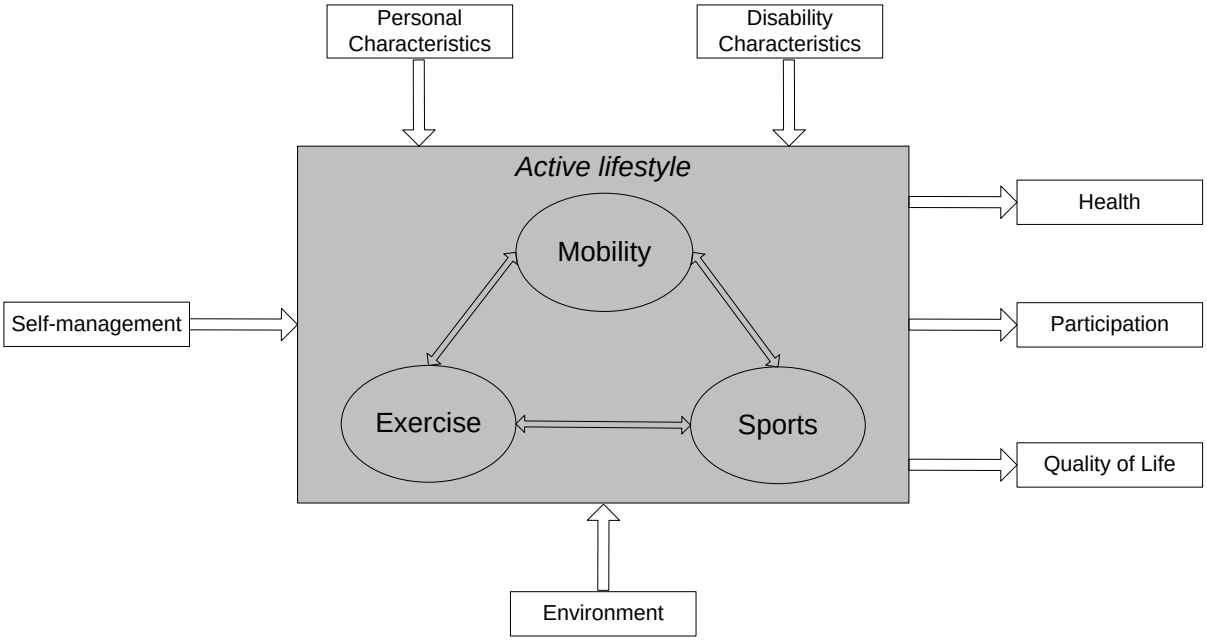

Figure 1. Association among and importance of the congress themes Mobility, Exercise and Sports in the context of rehabilitation.

Mobility

In the context of rehabilitation, restoration of mobility is often focussed on relearning walking or when that is no longer possible to learn wheelchair propulsion. Motor learning is a crucial yet highly underexposed topic in the context of rehabilitation (research). Understanding the unique motor control issues of people with a disability, such as in- and out-phase movements of the extremities, and the effect of (variable) training on these issues needs further investigation [11, 12].

In the Netherlands, wheelchair research has a history of over thirty years and has focussed on the biomechanical and physiological aspects of the wheelchair itself (e.g. its mass [13]), the wheelchair-user interface (e.g. seat height [14]) or the user (e.g. learning process [15, 16]), wheelchair skills [17, 18], fitness [19]). But also the positive effects of handcycling compared to wheeling in terms of its higher efficiency [20] and decrease in load on the upper extremities [21] were studied.

Through scientific research, technological developments entered the rehabilitation centers. Technology became available to monitor patients and help them to regain mobility and functional

ability during treatment. Nowadays, almost every rehabilitation center has its own gait lab. These labs are equipped with e.g. video cameras, force platforms and electromyography to be able to evaluate the walking ability of patients in detail and to evaluate different intervention strategies. To interpret the outcomes of these gait analyses in a clinical context, salient movement aberrations have to be identified and related to underlying impairments and functional gait problems. To assist evaluations and interpretations, software has been developed to show the signals of force and muscle activity during walking together with the video recordings in a clinical meaningful way, while observation and interpretation schemes have been developed [22] (Figure 2). This development requires multi-disciplinary collaboration and expertise. Still, it remains a challenge to focus these data towards more accurate diagnostic outcomes of mobility impairments and to further optimize effectiveness of current interventions.

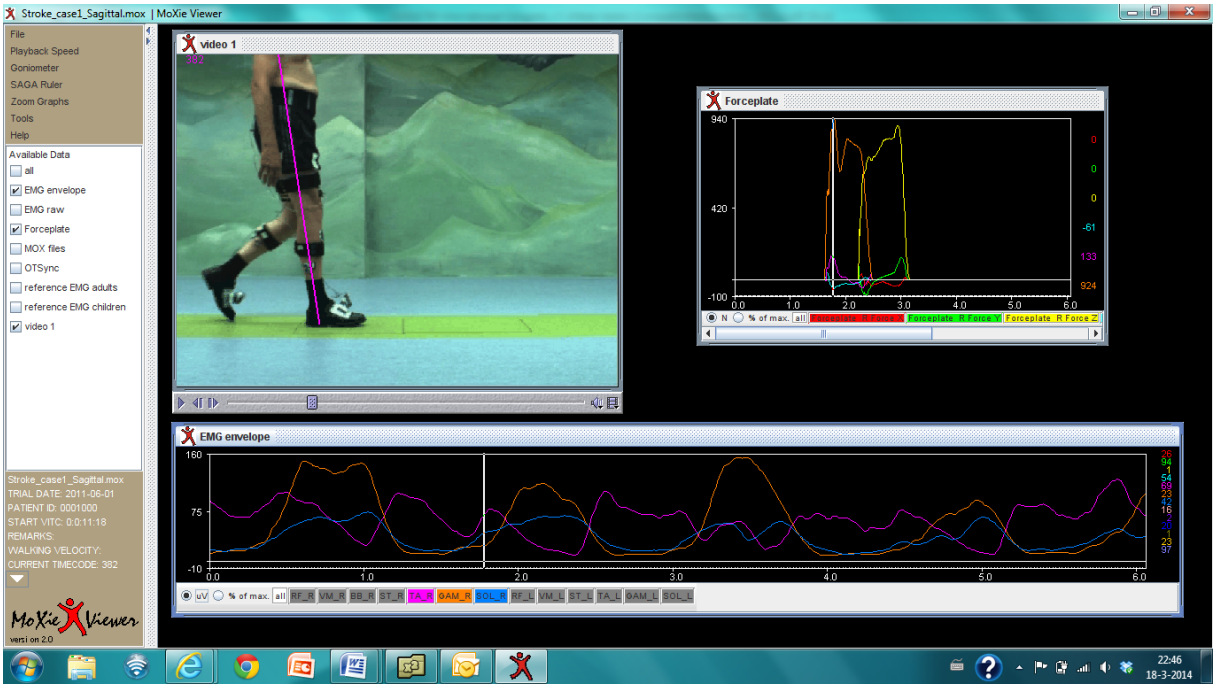

Figure 2. The MoXie Viewer: software for synchronously viewing video and concurrently acquired signals such as force and EMG data.

Besides these biomechanical measurements, and following the recognition of cardiorespiratory stress, strain and capacity being fundamental to successful rehabilitation outcomes, metabolic equipment is increasingly used today to study capacity, stress and strain of ambulation in patients. Patients with impaired gait, such as those with an amputation, often have high energy expenditure during walking [23-24]. This leads, together with their low aerobic capacity [24], to a high physical strain during walking. This physical strain has been found to be a potential predictor of walking ability in people after lower-limb amputation and should be taken into account when evaluating the clinical effectiveness of prosthetic componentry [23], by assessing both the metabolic demand of walking as well as metabolic capacity of the individual. The combination of metabolic and biomechanical phenomena has helped to start understanding the high cost of mobility for e.g. people with a stroke, amputation [23-25] or cerebral palsy [26], as well as in wheeled mobility [15].

Besides these new monitoring techniques, sophisticated ((robotic) or virtual-reality based) devices to train walking have been developed and implemented in the rehabilitation centers. It is important to study the effects of these, sometimes expensive, new therapies. Therefore, the

effectiveness of robot-assisted gait training with the Lokomat was studied in people with SCI and stroke [27]. For patients who are able to walk independently, the C-mill was developed to train gait adaptability on an instrumented treadmill augmented with visual targets and obstacles [28]. The effect of this kind of training is now investigated in a randomized-controlled trial in elderly [29].

Exercise

Chronic physical conditions have an impact on everyday physical activity, with persons with for instance transtibial amputation, spinal cord injury and myelomeningocele (wheelchair dependent) showing the lowest levels of activity, i.e. less than 40% of the able-bodied level [30]. Due to this inactive lifestyle, people with a disability show a decline in health post-rehabilitation [31]. An active lifestyle has a positive effect on health such as cardiovascular disease and fitness [32]. As a result of improved fitness, participation [33] and quality of life [34] can improve as well. Promoting an active lifestyle is thus very important for people with a disability and the position stand 'Exercise = medicine'[vi] by the American College of Sports Medicine is inherently true for people with a disability.

The question is how to induce and maintain and active lifestyle? There are physical activity guidelines for healthy adults, which may partly apply to adults with disabilities [35]. Important is that an individual physical activity program takes into consideration individual preferences, physical health limitations, and physical fitness [35]. Furthermore, a variety of exercises can be incorporated into physical activity programs [35]. Five years ago the Dutch Organisation for Health Research and Development (ZonMw) started a second research stimulation rehabilitation programme. Two of these research programmes, Learn2Move and ALLRISC, focussed on improving an active lifestyle. Learn2Move investigates the effect of an active lifestyle stimulation programme on activities in daily life and the development of an active lifestyle in children [36] and adolescents [37] with cerebral palsy. ALLRISC addresses inactive lifestyle, de-conditioning and secondary complications in people with a chronic SCI by self-management and physical training interventions [38]. A similar study (a combined exercise and behavioural intervention) is also performed during SCI rehabilitation. Not all results of these interventions have yet been published but although there were some positive results, other results were quite disappointing. For example, the physical activity stimulation programme for children with cerebral palsy (a combination of counselling, home-based physiotherapy and fitness training) was not effective in improving social participation in recreation and leisure [39].

It is a big challenge to get and keep people with a disability active since it is a multi-factorial problem, including among other things economic issues, emotional and psychological barriers, equipment barriers, professional knowledge, perceptions and attitudes of persons who are not disabled, including professionals [40]. Rehabilitation professionals and fitness trainers should play an important role in assisting people with a disability into general physical activity leisure activities and sports [41] over the lifespan to prevent long-term deconditioning in the first place. According to Rimmer [31], effective prevention of secondary health conditions due to inactivity must begin at the moment formal rehabilitation ends. A sports desk is implemented for that purpose in 18 Dutch rehabilitation institutes, where persons with a disability can get personal advice and support by a sports and movement consultant using a motivational interviewing approach. The main goal is that an active lifestyle becomes a permanent part of the person's daily life. A multi-center prospective cohort study investigates the underlying working mechanisms and the cost-effectiveness of this active lifestyle and sports stimulation program in both in- and outpatient rehabilitation care in specialized centers and general hospitals[vii].

Sports

Sports is defined as 'an activity involving physical exertion and skill in which an individual or team competes against another'. Optimizing technique, skills and fitness are important during rehabilitation but, on a higher level, also in elite adapted sports. A good example of this continuum between mobility, exercise and sports during and after rehabilitation is the Handbike Battle[viii], a 20 km mountain time trial (900 m elevation) among teams from eight Dutch rehabilitation centers. Most of the participants learned to handcycle during rehabilitation for mobility purposes. Thereafter, they used an (attachable) handcycle in daily life for mobility and exercise and by doing so were able to maintain an active lifestyle. For the Handbike Battle they took the next step, purchased a fixed-frame handbike and optimized their performance for a specific purpose, i.e. competing against themselves or others when handcycling up a mountain.

This race was organized 65 years after the first adapted sports competition was organized involving World War II veterans at Stoke Mandeville. In Rome, the first Paralympics were organized (1960). The number of athletes increased from 400 athletes from 23 countries in 1960 to 4301 athletes from 164 countries in London in 2012. The Paralympics increased media attention and opened opportunities for athletes to become professional sportsmen. In elite adapted sports issues like classification, doping and assistive technology are important to consider regarding fair play. The purpose of classification is to minimise the impact that severity of impairment has on the outcome of competition [42]. There is, however, very little scientific literature evaluating the relationship between impairment and athletic performance [43]. Therefore, the International Paralympic Committee (IPC) started the Athletics Classification Project that began in 2003 and aims to develop a taxonomically valid, evidence-based system of classification for athletes [44].

In most professional sports there are athletes who seek improved performance through the administration of banned substances, i.e. doping [45]. A doping method that is unique to sportsmen with spinal cord injury is called 'boosting', the intentional induction of autonomic dysreflexia to enhance performance [46]. Besides autonomic dysreflexia, other possible risks of the extreme strain associated with competitive sports are musculoskeletal injury and thermal dysregulation [47]. Upper-extremity overuse injuries are common in wheelchair users [48] and should be prevented since wheelchair athletes also need their upper extremity for essential daily activities [47] and over the lifespan. Individuals with spinal cord injury often have reduced sweating capacity leading to an increase risk of heat strain [49]. Cooling interventions [49], but also respiratory muscle endurance training [50] or supplementation strategies (e.g. caffeine, basic salts) [51] have the potential to enhance elite sports performance.

Another disability-specific dimension is assistive technology, i.e. the sports wheelchair or prosthesis. This can lead to 'technical boosting', which refers to an athlete's use of advanced technical equipment such as dedicated running prostheses or wheelchairs made of ultra-light materials [43]. Rapid progress is currently made in designing assistive technology to extend the boundaries of performance for disabled athletes. Computer modelling of the musculoskeletal system and the user-interface to these assistive devices, can be used to investigate the effect of changes in for instance a lower-limb prosthesis on balance and energetics during running and further optimize prosthetic design and athletic performance [52]. Such developments also come with ethical and philosophical considerations. Not every athlete will have access to this high-level equipment. Furthermore, with these assistive technologies Paralympic athletes might even function at higher levels than their Olympic peers. A good example of these ethical considerations is the debate about whether the use of Oscar Pistorius' prosthesis was a technical aid that gave him an unfair advantage [53].

Although quite some research has been performed in the Dutch rehabilitation field the last 10-15 years, the collaboration between human movement sciences and Paralympic sports has a shorter

history in the Netherlands. In 2012, the Dutch Paralympic committee invited a group of Dutch rehabilitation scientists to visit the Paralympics in London and to discuss subjects for study with the Paralympic coaches. Meanwhile research activities following this initiative, smaller and larger, have been started in this area, for example, on talent scouting, science-driven athlete performance enhancement in athletics, handcycling, and wheelchair tennis, the development of the 'perfect basketball wheelchair' and classification in handigolf. Besides, collaboration between the IPC and human movement and rehabilitation sciences over the world is established by projects involving the development of evidence-based systems of athlete classification for different Paralympic sports disciplines [44].

The future and beyond….

A critical problem of research in the field of rehabilitation and adapted sports is often the sample size. Case studies can be very interesting when the athlete is monitored over time. To be able to increase the sample size, multi-site (inter)national studies on patients or athletes are of utmost importance. Standardized techniques, protocols and outcome measures are necessary to be able to compare results of different research groups and also to combine the datasets to enlarge the sample size and to draw firmer conclusions. For that reason, the European Research Group in Disability Sports was established in 2013 to collaborate with several research groups in Europe on disability sports issues.

At the moment, there is a shift from lab-based testing to more field-based testing. Field-based testing offers the opportunity to have results that come closer to the actual rehabilitation or sports performance [54]. However, standardization is also very important for field-based testing and new technological developments (i.e. mobile and smaller measurement devices) are necessary. Therefore, the industry is an important partner in collaboration with rehabilitation and sports practice and science.

Studying the themes Mobility, Exercise and Sports should be done from a broad perspective, e.g. with biophysical and behavioural strategies. As said before, strategies to improve self-management are very important besides improving the assistive device or the fitness level of the patient or athlete. To gain more knowledge on the themes, a broad perspective regarding the design of the research study is also important. Experimental studies combined with epidemiological strategies (e.g. longitudinal studies) should be set up to be able to answer research questions on both a fundamental and practical level.

This all will require continued collaborations among many disciplines with many expertises. The State-of-the-Art congress brings together experts from these many disciplines (human movement sciences, engineering, health sciences, and from the field of rehabilitation and sports) to collectively explore and extend current knowledge and existing questions regarding Mobility, Exercise and Sports. This meeting stimulates collaboration and pushes forward the current developments and contributes to unlimited and healthy participation of people with disabilities in society and over the lifespan.

Implementation & Innovation: new steps to be taken?

As another consequence of the continued research collaboration, applied exercise physiology, biomechanics and motor control have or are entering today's rehabilitation (and adapted sports) practice through changing treatment and training protocols and guidelines and in the growing use of technology-driven training and monitoring systems. Embedded scientists are required here and are valuable for good and continued collaboration with patients/clinicians or athletes/coaches, between professionals and academia to further close the gap between practice and science.

Knowledge brokers must help break down the immense volume of research activity into accessible protocols and guidelines. Human movement scientists can be instrumental in those roles as well.

Current debate is on the need for a rehabilitation model over the lifespan, where specialist knowledge is available for chronic patients, thus helping to prevent secondary health problems in an early stage, improving quality of life and reducing societal costs for health care in growing numbers of elderly patients with chronic disease.

Other than research alone, there is the continued need for implementation of research results and new knowledge on 'mobility, exercise and sports' in daily rehabilitation and sports practice, as well as in general health care and society. 'Exercise = medicine' is not only to study, but also to teach, to 'preach', and to happen and experience. The built environment is a crucial element, such as a good walking infrastructure with attractive surroundings both indoors and outdoors, which stimulates or hampers an active life. The Netherlands, the location of the 2014 State-of-the-Art congress, provides an ideal surrounding for an active biking or walking lifestyle. However, also here much still can be changed to improve a far more active lifestyle for all.

'Healthy Aging' is a driving ambition of the Northern region of the Netherlands and, therefore, it should embrace even more explicitly active mobility, exercise and participation as key elements in healthy behaviour and today's health care, both in medical guidelines as well as a part of the physical and social environment. Although some initiatives are set off and promising plans are in development, the indoor environment in leading University Medical Centers – albeit at work or as a patient in the hospital - has far more opportunities to be stimulating towards a physically active lifestyle or active participation; 'exercise as a medicine' seems not yet fully advocated among professional opinions or leaders. It is a challenge for a medical center to evolve to an exercise and movement-stimulating hospital (in Dutch: 'beweegziekenhuis'), a hospital that expresses healthy aging, active lifestyle and 'exercise = medicine' in its essentials. Among all other aims of the present congress, we also hope to reach those professional leaders that can and will make the difference, change current practice, train future professionals in 'exercise = medicine' and thus improve medical (rehabilitation) care for future generations and over the lifespan.

[i] www.zonmw.nl/en
[ii] www.scionn.nl
[iii] www.bewegingswetenschappen.org
[iv] www.revalidatiegeneeskunde.nl
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Oral presentations
Wednesday, April 23, 2014

Keynote lecture 1: Prof. Dr. K. Newell

Principles of Learning and Motor (Re-)Learning in Rehabilitation

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In this talk I will examine issues within the assumption, common in both the theory and clinical practice of movement and action, that the principles of motor learning carry over to motor (re-) learning in rehabilitation. This working assumption prevails regardless of the theoretical framework (e.g., information processing, cognitive theory, computational biology, ecological approach to perception and action) used to investigate learning and/or re-learning and it tends to be unidirectional from learning to re-learning though it does not in principle need to be asymmetrical. It is proposed that this working assumption is in effect a generalization view of the processes of change in movement and action even though there are performance decrements and differences in movement and physical activity that are sought to be ameliorated through practice and rehabilitation strategies.

There has been an increase in recent years in the number of research studies published on the processes of motor re-learning in rehabilitation. Most of these studies are focused on applied questions that arise from the emphasis on the practical necessities, goals and implications of the recovery of function but there is also an increasing interest in the pursuit of the general principles of behavioral change in rehabilitation. Thus, the integration of basic and applied research agendas in motor learning is sought in many of the subdomains of rehabilitation.

I will explore in the talk the hypothesis that follows from this approach: namely, that the motor performance decrements and different pathways of change that arise through aging, injury and disease over the lifespan are due to changing constraints on action, particularly organismic constraints, rather than differences in the principles that characterize the change processes of adaptation, development and learning. In this context, the role of the confluence of constraints in action and rehabilitation is discussed with emphasis on the interaction of the structural and functional constraints that arise from the individual engaged in motor tasks (Newell, 1986) and in the pursuit of the recovery of function. In this context, it will be argued that a lifespan approach to rehabilitation that encompasses the traditionally separate ideas of learning and development provides a more inclusive framework than drawing from the theory traditions of motor learning alone – given their original basis in the associative tenets of learning theory in psychology.

In the talk we decompose the potential of these general theoretical issues though the particulars of the operational assumptions for the different classes of movement tasks (locomotion, posture, manipulation) and the different learning/re-learning strategies of intervention (with emphasis on practice schedules and information). Thus, we examine the proposition that the learning and re-

learning generalization holds across the fundamental activity categories and the fundamental intervention strategies for motor learning and the acquisition of skill. The approach to motor learning and re-learning sketched here is related to and compatible with the ideas about motor control that have been developed from Bernstein's account of movement coordination and control and elaborated into the related approaches of coordination dynamics and the ecological psychology theory of perception and action.

That the generalization account of learning and re-learning holds is consistent with the perspective that the persistent and transitory changes in task outcome are products of the dynamical stability and instability realized from the changing and different time scales of the evolving attractor landscape, bifurcations between attractor organizations, and the transient phenomena associated with moving toward and away from fixed points (Newell, Liu, & Mayer-Kress, 2001; Newell & Liu, 2014). In this view, there is a small set of functions of change at the behavioral outcome level of movement and action that emerge from the persistent and transient changes in the coordination dynamics. Task demands and their interaction with constraints of the individual learner are significant determiners of the nature of the observed changes with learning. It is anticipated that the variety of particular constraints of the many learning situations in rehabilitation will lead to different pathways of change than those of exponential and power laws that have dominated the observed functions of human motor learning. The role of transitions in coordination dynamics is likely to play a significant role in re-learning motor skills given the need to form (re-form) a task-relevant coordination pattern that initially in recovery is unavailable.

There is considerable evidence that the skill level and general developmental status of the learner should play a significant role in the construction of the conditions of learning and the application of instructional strategies. Thus, instructional strategies need not only to be task relevant but tailored to the constraints of the individual learner. This means that the conditions of learning should not be static (unvarying over practice sessions) but rather dynamic and progressively tailored to the learner and the learning situation.

It is against this theoretical background that the many instructional strategies for motor learning can be assessed and interpreted. The two major intervention strategies in motor learning are those that manipulate and determine: a) the work/rest cycle of the trial-to-trial sequence; and b) the availability of informational support of the movement trials in learning a given action. There are examples of both of these classes of instructional strategies in the re-learning of rehabilitation and indications of complementary and counter findings to those from the learning domain.

It is interesting that the relatively recent emphasis on the significant positive influence of massed practice in the recovery of limb motion in rehabilitation following stroke is counter to the traditional finding and synthesis from the motor learning domain which hold that distributed practice leads to more rapid learning and higher levels of performance than massed practice. This is one example of an apparent contrast between a principle of learning and re-learning in motor skills. However, the contrasting findings may not be so straightforward as is typically assumed.

The presentation of augmented information in motor learning can take many forms in terms of both the information presented and the medium for the presentation (Newell, 1996). Again, the hypothesis is that the information to be presented depends upon the task to be learned and the skill level of the learner. And, while the many forms of feedback (e.g., KR, concurrent FB) can often be used by learners there can be benefits in learning from prescriptive information (demonstrations, instructions) and transition information (information that relates to a particular change in coordination). The relative effectiveness of these categories of information are task and learner dependent and can be characterized in terms of the channeling of a task-relevant search strategy for learning stable task solutions. The role of technology as physical and informational support for the learner requires parallel considerations to those for augmented information in

general, but can bring with it special considerations. The central question is still what information is most relevant to the task relevant change.

Instructional strategies in re-learning and rehabilitation require not only a thorough assessment and understanding of the status of the learner as provided by the medical community but also a clear understanding of task constraints and importantly, their potential interaction with those that the individual learner brings to the re-learning situation. The therapist, as the instructor or coach in motor learning, needs an understanding of how to channel the search by the learner for task-relevant movement dynamics. Skilled change agents have learned through experience how this search process can best be effected in terms of learning strategies for a given learner in a given task.

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Oral presentations
Wednesday, April 23, 2014

Session 1: Motor Learning

Inter-individual differences, intra-individual variability and motor learning in handrim wheelchair propulsion

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Abstract Handrim wheelchair propulsion is a complex bimanual motor task. The bimanually applied forces on the handrims determine both the speed and direction of locomotion. In our experiments on the motor learning of steady-state wheelchair propulsion at a motor driven treadmill, at a fixed speed and power output, a high variability in force application and timing between the simultaneous pushes on the left and right side are found, as well as within one side over time. Possibly, the amount of variability within individuals relates to the motor learning process of new wheelchair-users. During the first twelve minutes of learning, individuals already changed their propulsion technique, reduced in inter-cycle variability and increased their mechanical efficiency. Besides these changes over the whole group further examination showed differences in learning between two groups of learners. The initially slow improvers started with a higher mechanical efficiency, but did not increase much, while the initially fast improvers started lower, yet increased more, ending at a similar efficiency level compared to the first group after only twelve minutes of practice. In a follow up study we tried to get further insight in the differences between these two groups and their results during practice over a longer time scale (80 min). Eventually the initially fast improvers benefitted more from the given practice indicated in elements of improved propulsion technique (i.e. reduced frequency, increased stroke angle) and a higher mechanical efficiency. The initially fast improvers also had a higher intra-individual variability in the pre- and posttest, which possibly relates to the increased motor learning of the initially fast improvers. Further exploration of the common characteristics of different types of learners and the relation of intra-individual variability with motor learning will help to better tailor rehabilitation to the needs of wheelchair-dependent persons and improve our understanding of cyclic motor learning processes.

Keywords Rehabilitation; Biomechanics; Motor Learning; Wheelchair

Introduction

Handrim wheelchair propulsion is a complex bimanual motor task. The bimanually applied forces on the handrims determine both the speed and direction of locomotion. In our experiments into motor learning of steady-state wheelchair propulsion on a motor driven treadmill at a fixed speed

and power output, a high variability in force application and timing between the simultaneous pushes on the left and right side are found, as well as within one side over time [1,2]. This intra-individual variability is intrinsic to human movement and is assumed to not only be the reflection of noise and/or error, but also to be functional and to contain features that may provide insight in motor learning [3-5] and pathological processes [6-10]. From this perspective, intra-individual variability is seen as a mechanism allowing individuals to adapt their movements as a function of organismic, environmental and task constraints [11,12] and towards intrinsic optimum levels of energy cost and coordination.

Methods

Wheelchair propulsion is a cyclic task, which makes it possible to evaluate steady-state submaximal performance using energy consumption from respiratory measurements. Therefore mechanical efficiency, the ratio of external power output over energy expenditure, can be used as a generic outcome measure of motor learning [13]. Different studies have shown that through practice individuals learn to reduce their energy expenditure while performing at the same external power output [1,2,14-17].

Results & Conclusion

Changes in propulsion technique can be monitored using measurement wheels with instrumented handrims. Through motor learning the changes in propulsion technique are thought to attribute to the increased mechanical efficiency. Using multi-level analysis it was shown that the negative work per cycle contact angle, push frequency and net work per cycle related most to the changes in mechanical efficiency of novice able-bodied users over the first 12 minutes of practice [2].

Figure 1 shows a typical example of 12 consecutive pushes displayed in a polar plot. Along the radius the torque is plotted against the contact angle, thus each push makes a closed shape. This was the high variability in the pushes is easily noted as the differences in the shapes. The coefficient of variation (CV), the percentage standard deviation of the mean, was used to evaluate changes in intra-individual variation because of practice. Over the 12-minutes of practice the CV reduced for these parameters over the whole group.

Additionally we defined two groups of learners based on a lower or higher than 10% relative increase in mechanical efficiency and followed them over a longer timescale (80-minutes). The initially slow improvers, started with a higher mechanical efficiency better propulsion technique and a lower coefficient of variation during the first 12 minutes. However they did not increase much during practice. The initially fast improvers on the other hand started with lower scores on mechanical efficiency and propulsion technique and had a higher CV, but increased more because of the 12-minutes practice [2].

Over 80-minutes of practice the initially fast improvers benefitted more, indicated by a better propulsion technique (like reduced frequency and increased stroke angle) and a higher mechanical efficiency [18]. The initially fast improvers also had a higher intra-individual variability in the pre- and posttest, which possibly relates to the increased motor learning of the initially fast improvers. Further exploration of the common characteristics of different types of learners and the relation of intra-individual variability with motor learning will help to better tailor rehabilitation to the needs of wheelchair-dependent persons and improve our understanding of cyclic motor learning processes.

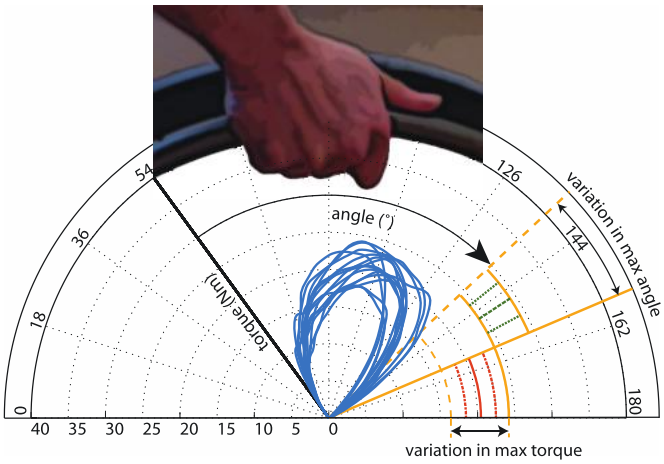

Figure 1: Polar plot of the torque against the angle for 12 pushes, showing the intra-individual variation in contact angle and maximum torque. Since no position data were recorded each push is started from the same arbitrary angle. (Adapted from [18])

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Effect of functional or force control training tasks used for intermanual transfer in upper limb prosthetic training

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Abstract The aim of this study is to determine which type of training task has the largest intermanual transfer effect when training with a myoelectric prosthetic simulator. To achieve the best results prosthetic training should start early after the amputation and intermanual transfer can be used for this (Romkema, Bongers et al. 2013). Intermanual transfer implies that motor skills learned at one side of the body, transfer to the other side. To start prosthetic training immediately after the amputation a prosthetic simulator on the sound arm can be used. To determine which tasks have the largest intermanual transfer effect, different training tasks will be examined. Able-bodied right-handed participants (N=36) were randomly assigned to one of two experimental groups or one control group. The experimental groups performed a five-day training program with a simulator that could concentrate on force control or on functional tasks. The training program was performed with one arm; tests were performed with the other arm,during pretest, posttest and retention test sessions. During test sessions in which movement times and the error in the force control were measured. The force control test showed significant ($p<.001$) improvement of the force control training group compared to the control group in the posttest. This implied that when training force control this could transfer to force control at the other side. It therefore is assumed that intermanual transfer can be useful for grip force control training with a prosthesis.

Keywords Upper limb prosthesis, intermanual transfer, prosthesis training

Introduction

Prosthetic training should start within the first month after amputation for the best results (Malone, Fleming et al. 1984). To start training for prosthetic use immediately after amputation, intermanual transfer can be used (Romkema, Bongers et al. 2013). Intermanual transfer implies that motor skills learned at one side of the body, transfer to the other side. This suggests that by practicing the unaffected arm, in the period between amputation and prosthetic fitting, the affected arm can also improve. To determine which tasks are most effective for intermanual transfer training two training tasks were examined. First, functional tasks, that earlier showed intermanual transfer effect in prosthetic training and second, force control, which is a part of prosthetic handling that is relative hard to learn.

Methods

Participants and Design

Thirty-six able-bodied participants between 18 and 40 were recruited and randomly assigned to one of three groups (Figure 1). Participants started with a pretest using a prosthetic simulator (Figure 2) on the test arm (day 1). Then they practiced for five days with the other (training) arm (day 1-5) for 15 minutes each session. After the training sessions a posttest (day 5) and retention test (day 11) were executed. For half of the participants the dominant side was tested, and for the other half the non-dominant side was tested.

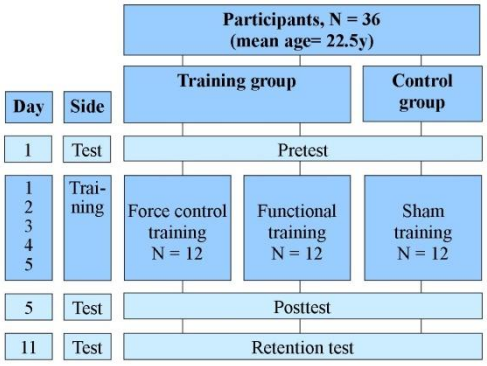

Figure 1. Experimental design



Figure 2. Prosthesis simulator.

Training

To train the control of force delivered with the prosthetic hand, three tasks were used: the object, the tracking and the matching task. In the object tasks deformable objects had to be picked up and compressed as little as possible (Figure 3a,(Bouwsema, Kyberd et al. 2012)). For the tracking and matching tasks participants had to press an object containing a force transducer held with the prosthetic hand. The produced force was depicted on a screen. In the tracking task participants had to follow a line with the produced force (Figure 3b). In the matching task the produced force had to reach a point designated on a bar.

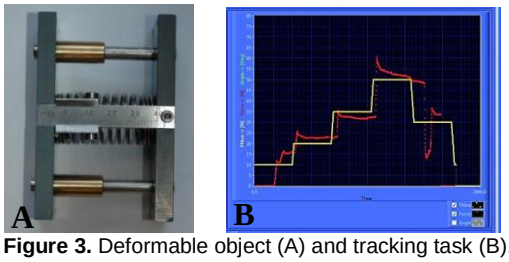

Figure 3. Deformable object (A) and tracking task (B).

The functional training tasks contained ten functional tasks executed with the simulator.
The control group executed a sham training, in which they used the training hand without simulator to execute the SHAP and Purdue pegboard.

Pretest, posttest, retention test

To measure grip force control participants performed the tracking task three times. The mean absolute error of the requested force (N) was used as dependent variable. During the functional tests the movement time of three test tasks (picking up a mug, opening a jar lid and opening a pen case were assessed.

Data analysis

We performed one Repeated Measures ANOVA on the functional tasks and one on the force control tasks. In both analyses we compared the training group that trained on this task with the control group.

Results

A Repeated Measurements ANOVA on the error in the force control showed a significant ($p<.05$) improvement of the force control training group compared to the control group in the posttest. No significant differences between the functional training group and the control group were found in a Repeated Measurements ANOVA on movement times.

Conclusion and discussion

Training with a prosthetic simulator specifically focusing on grip force control can transfer to the contralateral arm. This finding might be important for the rehabilitation of patients who recently underwent an amputation, because force control with a prosthesis is hard to learn.

Contrary to earlier findings, we did not find a significant difference in the movement time of the functional training and control group. Reasons for this may be that the training was not long enough or that the sham training also caused improvement. This finding deserves further study.

Acknowledgements

We would like to thank Johan Horst and Theo Schaaphok for their technical assistance with the simulator, and Emyl Smid, Wim Kaan, and Henry van de Crommert for assistance with preparing the experimental equipment.

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Unilateral versus bilateral upper limb training after stroke

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Abstract Within the plethora of treatment methods for the paretic upper limb, unilateral and bilateral training protocols represent conceptually contrasting approaches with the same ultimate goal. In the Upper Limb TRaining After stroke (ULTRA-stroke) project, unilateral and bilateral upper limb training were compared with each other to assess the effectiveness of these interventions and to examine how the observed changes in sensori-motor functioning relate to changes in interlimb interactions. A systematic review and meta-analysis revealed no clinically relevant significant differences in effectiveness between unilateral and bilateral training in patients with acute and chronic stroke. A randomized clinical trial comparing unilateral, bilateral, and dose-matched conventional upper limb training with patients starting the intervention between 1-6 months after stroke showed similar results: no significant differences in change scores regarding clinical effects and bilateral coupling were found between groups. However, the bilateral training group showed more control over the paretic hand (i.e., greater movement harmonicity and larger wrist amplitudes) after training than both other groups. Conclusion: unilateral and bilateral training are not superior to dose-matched conventional treatment or each other in improving upper limb sensori-motor functioning after stroke. Although more control over the paretic hand after bilateral training may indicate a beneficial influence of bilateral coupling during training, this improvement did not translate into better outcomes on clinical measures in favor of bilateral training.

Keywords Stroke, upper limb, rehabilitation, constraint-induced movement therapy, bilateral arm training

Introduction

Recent developments in post-stroke upper limb rehabilitation have provided a plethora of treatment methods for the paretic upper limb (Langhorne, Coupar et al. 2009). Remarkably, within this collection two therapeutic concepts figure prominently that represent diametrically opposed views as to how the use and function of the paretic upper limb may be improved. On the one hand there are therapies that deliberately prevent the use of the non-paretic upper limb, such as Constraint Induced Movement Therapy (CIMT; Wolf, Winstein et al. 2006). On the other hand there are therapies that advocate utilization of the non-paretic upper limb to enhance motor function in the paretic limb, such as Bilateral Arm Training with Rhythmic Auditory Cueing (BATRAC; Whitall, McCombe-Waller et al. 2000). This dichotomy between unilateral and bilateral approaches of upper limb training after stroke is an interesting subject for research for several reasons. First, unilateral upper limb training, in particular CIMT, is an established rehabilitation intervention, which is recommended in various therapeutic guidelines (Langhorne, Coupar et al.

2009), whereas bilateral upper limb training is only making its mark in the past 15 years. Second, both approaches have different theoretical backgrounds, while serving the same, ultimate goal, i.e., lasting improvement of upper limb function after stroke. In the Upper Limb TRaining After stroke (ULTRA-stroke) project, unilateral and bilateral upper limb training were compared with each other to assess the effectiveness of these interventions and to examine how the observed changes in sensori-motor functioning relate to changes in interlimb interactions.

Methods

A systematic review and meta-analysis of randomized clinical trials with sensitivity analyses for severity and time of intervention post-stroke were performed. Literature was searched in the PubMed, EMBASE, Cochrane Central Register of Controlled Trials, CINAHL, Physiotherapy Evidence Database (PEDro), SportDiscus, and OT-Seeker databases.

In addition, a single blind clinical trial was conducted. Sixty patients, between 1 to 6 months after stroke, were randomized over 3 intervention groups: modified CIMT (mCIMT), modified BATRAC (mBATRAC) and a dose-matched control intervention (DMCT). The primary clinical outcome measure was the Action Research Arm test (ARAT), which was conducted before, directly after, and 6 weeks after intervention. With a series of unilateral and bilateral rhythmic coordination tasks we also investigated changes in intended and unintended coupling effects between the hands and control over the paretic hand as reflected by movement harmonicity (as a measure of movement smoothness) and amplitude.

Results

The literature search resulted in 9 studies. All studies, involving 452 patients, showed homogeneity. In chronic patients with a mild upper limb paresis after stroke a marginally significant Standardized Mean Difference (SMD) for upper limb activity performance (SMD 0.34; 95% confidence interval: 0.04–0.63), and marginally significant Mean Differences (MDs) for perceived upper limb activity performance (amount of use: MD 0.42; 95% confidence interval: 0.09–0.76, and quality of movement: MD 0.45; 95% confidence interval: 0.12–0.78) were found in favor of unilateral training. All other MDs and SMDs were non-significant.

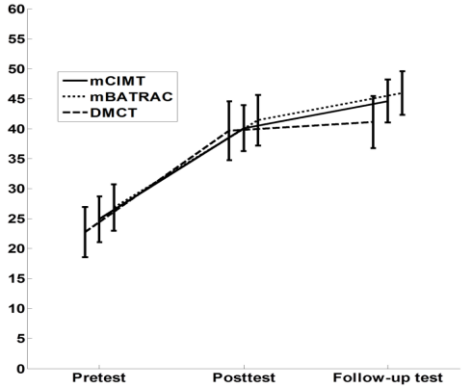

Figure 1. Mean Action Research Arm test scores (and SEs) over time per group. Group-lines are shifted horizontally to enhance clarity. DMCT indicates dose-matched conventional treatment; mBATRAC modified bilateral arm training with rhythmic auditory cueing; and mCIMT, modified constraint-induced movement therapy.

In the clinical trial, all groups (mCIMT, mBATRAC, and DMCT) demonstrated significant improvement on the Action Research Arm test after intervention, which persisted at 6 weeks follow-up. However, no significant differences in change scores on the ARAT were found between groups post-intervention and at follow-up. The results on the Action Research Arm test are presented in Figure 1.

The mBATRAC group showed greater movement harmonicity and larger amplitudes with the paretic hand after training than the mCIMT and DMCT groups in the unilateral and bilateral rhythmic coordination tasks (*P*'s<0.05). However, these differences did not translate into better outcomes on clinical measures in favor of bilateral training and there were no significant between-group differences in change scores from baseline to post-intervention and from post-intervention to follow-up regarding interlimb coupling.

Conclusion and discussion

From the systematic review and meta-analysis we conclude that unilateral and bilateral training are similarly effective. Although there were significant differences in effect in a specific group (chronic stroke patients with a mild upper limb paresis), the obtained effects were small and below the conventional threshold judged as clinically meaningful. The results of the clinical trial indicate that mCIMT and mBATRAC are not superior to DMCT or each other in improving upper limb function, in line with the results of the meta-analysis.

In the clinical trial the degree of coupling between both hands was not significantly higher after bilateral than after unilateral training and control treatment. Although improvements in movement harmonicity and amplitude following mBATRAC may indicate a beneficial influence of the interlimb coupling, those effects were more likely due to the type of movements employed during this training protocol.

Given the results of the ULTRA-stroke project and previous trials employing dose-matched interventions, the intensity of active exercise of the paretic upper limb may be more important than specific features that distinguish the training approaches, such as unilateral and bilateral training (Langhorne, Bernhardt et al. 2011).

Acknowledgements

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Oral presentations
Wednesday, April 23, 2014

Session 2: Wheeled Mobility

What change in manual wheelchair propulsion resistance can individuals with paraplegia sense?

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Abstract *Purpose:* To determine how accurate persons with paraplegia are at sensing wheelchair propulsion resistance changes and if accuracy is dependent on the magnitude or direction of change. *Methods:* 13 persons with paraplegia completed 36 one minute fixed speed (0.86 m/s) wheelchair treadmill trials (visit 1 =18, Visit 2 = repeated in reverse order). Each trial began at 1 of 4 initial resistances (Reference(R), R+2, R+4, R+ 6 Watts(W)). After ~30 sec, the resistance was manipulated (+/- 0W, 2W, 4W, or 6W) via a pulley system. R is the resistance of the individual's chair at 0.86 m/s plus the resistance of the attached, un-weighted pulley (2W). We visually blinded participants to initial resistance and the manipulation. After each trial, participants rated perceived resistance change (global change in resistance scale -7 to +7). No perceived change=-1, 0, +1, perceived change = -7 to -2 and +2 to +7. *Results:* N=8 men, mean (SD) age 37(13) yrs, injury duration 11(11) yrs. Overall accuracy (N=445 trials) was 54% with low agreement between actual change and perceived change (Kappa=0.30, p<0.00). Specific accuracies are (change(% accurate)): -6W(60%), -4W(46%), -2W(45%), 0W(49%), +2W(60%), +4W(67%), +6W(72%).Individual binary logistic regression models indicate accuracy a) increases as magnitude of change increases (p=0.031, df=3,χ2=8.9) and b) is greater when resistance increases vs. decreases (p=0.003, df=1, χ2=8.9). *Conclusions:* Persons with paraplegia appear to be more able to sense propulsion resistance increases or decreases ≥4W, but in general are more sensitive to resistance increases. We suggest that clinically this may mean that persons with paraplegia may be unreliably able to sense if a wheelchair configuration modification decreased rolling resistance unless the change was greater than 4W. For reference, the difference between pneumatic tires a 100% and 50% inflation is ~3W.

Keywords Wheelchair, Spinal Cord Injury, Rehabilitation, Paraplegia

Introduction

A key goal of manual wheelchair propulsion research is to assess how various factors affect propulsion biomechanics and energetics (e.g. wheelchair configuration/fit, propulsion technique, surface characteristics, etc…). Many of these factors affect biomechanics or energetics by altering the rolling resistance of the user-wheelchair system. For example, rolling resistance and the resultant demand on the user is increased by low tire pressure, solid tires, and a more posterior rear wheel position. The objective of research is to provide clinicians with an evidence

base that enables them to minimize user-chair system rolling resistance while accommodating user needs and preferences. Although we generally know what wheelchair modifications decrease/ increase rolling resistance, we know nothing about how sensitive users are to rolling resistance changes. The purpose of this project is determine how accurate persons with paraplegia are at sensing wheelchair propulsion resistance changes and if accuracy is dependent on the magnitude or direction of change.

Methods

Participants

Thirteen individuals with spinal cord injury/disease resulting in paraplegia participated. Participants averaged 11 (+/-11) years post-injury, 37 (+/-13) years of age, 70.2 (+/-17.5) kgs, and included 8 men.

Research Protocol

During each of 2 visits, participants completed 18 one minute propulsion trials, resting two minutes between each trial. Visit 1 trial order was randomized. To attenuate learning or fatigue effects, Visit 2 trial order was the reverse order of trial 1.

Each one minute trial was completed on a wheelchair treadmill at 1% grade and 0.86 m/s and consisted of a unique combination of starting power output and mid trial change in power output (Table 1). We manipulated power output via pulley system attached to the participant's own wheelchair. Participants began propelling at the predetermined starting power output (PO) and mid-way through the one minute trial we manipulated PO. Participants were visually blinded to the manipulation and had to rely on somatosensory input to detect the direction and magnitude of change. After each trial each participant rated any perceived resistance change (Global rating of change, 15 point Likert scale, A very great deal less resistance (-7), No difference in resistance (0), A very great deal more resistance (7)).

Table 1. Trial starting power output (PO) and PO manipulations tests (N=18). PO_{REF} is the resistance of the individual's chair at 0.86 m/s plus the resistance of the attached, un-weighted pulley (2W)

PO manipulations	Trial Starting Powers				
	PO_{REF}	PO_{REF}+2W	PO_{REF}+4W	PO_{REF}+6W	PO_{REF}+8W
No change	0	0	0	0	-
Increases (W)	+2, +4, +6	+2, +4	+2,	+2	-
Decreases (W)	-	-2	-2, -4	-2, -4, -6	-2

Data Reduction

A total of 445 one minute trials were available for analyses. Ten participants completed all 36 trials, two completed 34 trials, and 1 completed 17 trials. A trial was graded as accurate if the actual direction of the power output manipulation matched the direction of the participant's self-report perceived change (Table 2).

Table 2. Trial accuracy scoring metric (Accurate(A), Inaccurate (I); no change (~), PO increased (↑). PO decreased (↓).

Actual change direction	~	~	~	↑	↑	↑	↓	↓	↓
Subject reported change direction	~	↑	↓	~	↑	↓	~	↑	↓
Scoring	A	I	I	I	A	I	I	I	A
% of trials	11%	7%	5%	7%	25%	7%	8%	12%	18%

Statistics

We used Cohen's kappa to measure accuracy on all data (N=445 trials, actual change direction vs. perceived change direction). To determine if accuracy was dependent on magnitude of change, we examined the subset of trials that started at PO_{REF} (N=100 trials) using binomial logistic regression (independent = change magnitude, dependent=accuracy) To determine if accuracy was dependent on direction of change, we examined the subset of trials where PO was increased or decreased (N=345 trials). We set significance *apriori* at $\alpha<0.05$.

Results

Overall accuracy (N=445 trials) was 54% with low agreement between actual change and perceived change (Kappa=0.30, p<0.00). Specific accuracies are (change(% accurate)): -6W(60%), -4W(46%), -2W(45%), 0W(49%), +2W(60%), +4W(67%), +6W(72%). Accuracy increased as magnitude of change increased (p=0.031, df=3 $\chi 2=8.9$). For trials starting at PO_{REF}, accuracies are (change(% accurate)): +0W (48%) +2W(36%), +4W(68%), and +6W(72%). Accuracy is greater when resistance increases (63%) vs. decreases (47%) (p=0.003, df=1, $\chi 2=8.9$).

Conclusion and discussion

Persons with paraplegia appear to be more able to sense propulsion resistance increases or decreases greater than or equal to 4W. They also appear to be more sensitive to resistance increases than decreases. We suggest that clinically this may mean that persons with paraplegia may be unreliably able to sense if a wheelchair configuration modification changed rolling resistance unless the change was greater than 4W and are less likely to sense changes that decrease rolling resistance. For reference, the difference between pneumatic tires at 100% and 50% inflation is ~3W.

Acknowledgements

We thank the International Collaboration on Repair Discoveries and the Miami Project to Cure Paralysis for funding this project and Carla Pryor, Matthew Fritze, Nathan Hers, and Masha Sadeghi for assistance with data collection and data management.

Seat positioning effect on load distribution in manual wheelchair propulsion

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Abstract The purpose of this study was to evaluate the effect of seat positioning on loading distribution in maximum static propulsion effort of wheelchair users by using adjustable wheelchair ergometer developed by the Habilitation /Rehabilitation Centre in Sports Paralympic. Eight manual wheelchair users were evaluated randomly by adjustable ergometer associated with a device assessment calibrated of load distribution FSR (Force Sensing Resistor) positioned on the seat. The measurement of load distribution was held at the maximum propulsion to the 26" wheel rim locked. The wheelchair ergometer had no camber. The seat was positioned at a distance of 135 mm and 250 mm behind from wheel centre and with a height of 290 mm from the seat. Heating (1 min) and cooling (1 min) procedures were performed before and after the experiment. The measurement on loading distribution in maximum static propulsion effort of wheelchair users positioned at distance of 250 mm showed averaged 38.13 ± 2.03 N and the distance of 135 mm averaged 40.73 ± 2.71 N. This study observed a significant increase ($p = 0.04$, paired test t) in the load distribution approaching the seat to the wheel centre with maximum static propulsion effort of wheelchair users. Adjustments of the centre of gravity of wheelchair should consider distributing load in order to prevent secondary complications, improve comfort and mobility in a wheelchair.

Keywords Seat positioning, load distribuition, manual wheelchair propulsion

Introduction

The manual wheelchair propulsion is a mobility device, temporary or permanent used by individuals with mobility disabilities (Lin, 2009). The design and configuration of the wheelchair have evolved over the years due the constant advancement in technology. Adjustable wheelchairs allow professional and wheelchair users make changes in the configuration of the wheelchair. Changes in the position of the wheelchair seat to the axis of the rear wheel, wheel camber, varying backrest height and increasing handrim diameter are some examples of possible wheelchair modifications of configuration. The positioning of the seat (in horizontal and vertical directions) relative to the axis of the rear wheel (the position of the centre of mass) has been documented by significantly affect the biomechanical propulsion (Desroches, 2006).The seating position is one of the factors that influence the load distribution on the wheelchair seat. The distribution of loads in the chair seat is an aspect discussed in search for the appropriate

adjustment in the wheelchair-user interaction, to prevent secondary, improve mobility, functional independence and participation in sports activities (Samuelsson, 2004). The purpose of this study was to evaluate the effect of seat positioning on loading distribution in maximum static propulsion effort of wheelchair users by using adjustable wheelchair ergometer developed by the Habilitation/Rehabilitation Centre in Paralympic Sports.

Methods

Participants

Eight manual wheelchair users from Paraplegics Association of Uberlândia (APARU) were evaluated randomly. It was considered wheelchair users those who used wheelchair for at least 12 hours per day. As a criterion for exclusion individuals with mental deficiency and musculoskeletal injuries of the upper limbs who cannot perform manual propulsion in wheelchair. All participants were positioned for measurement considering anthropometric individual aspects and signed the informed consent. The work was approved by the research ethics (Protocol 315/07) Conep Committee.

Assessment and devices

The measurement of loading distribution on the seat used an adjustable wheelchair ergometer and its system consisted of 27 sensors arranged along the surface (340 x 340 mm) seat. The acquisition of data was associated with the processing and visualization of results software system sensors FSR. The measurement of load distribution is held at the maximum propulsion to the 26" wheel rim locked. The wheelchair ergometer had no camber. The seat was positioned at a distance of 135 mm and 250 mm behind from wheel centre and with a height of 290 mm from the seat. Heating (1 min) and cooling (1 min) procedures were performed before and after the experiment.

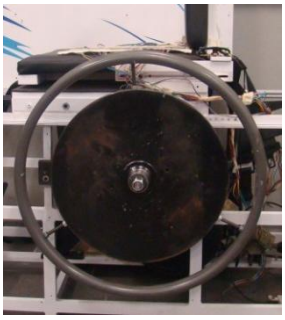

Figure 1. Show the wheelchair ergometer and the measurement of load distribution system.

Statistics

The results of load distribution were analysed employing descriptive and inferential statistics. It was used SPSS software, version 19.1. Quantitative variables were described using mean and standard deviation. The paired test was used to verify the correlation between the variables of load distribution in the two seat positions. The level of significance was 5% (<0.05).

Results

The sample consisted of 8 wheelchair users (4 males and 4 females) with the average age of 32 ± 11 years, mass 66 ± 11 kg being 4 users affected by myelomeningocele and 4 for spinal cord

injury. The results of load distribution on wheelchair ergometer seat when performing maximum static propulsion effort of 250 mm position observed a significant increase (p = 0.04, paired test t) in the load distribution approaching the seat to the wheel centre scores with averaged 38.13 ± 2.03 N and 135 mm position with averaged 40.73 ± 2.71 N.

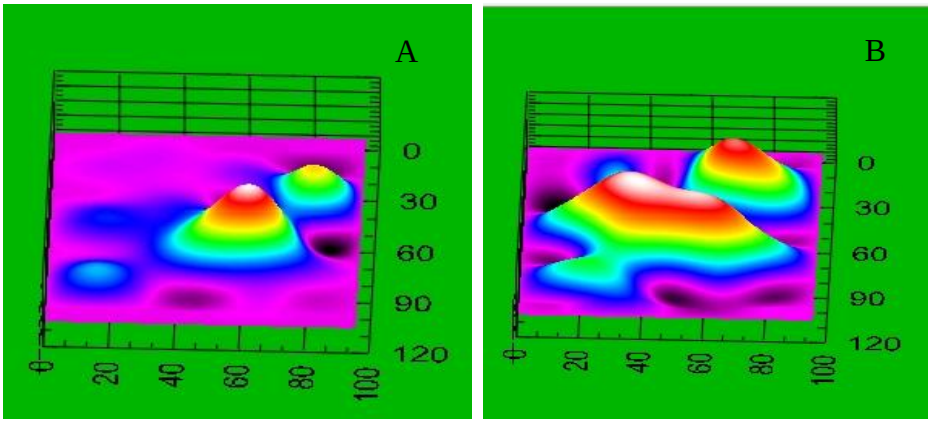

Figure 2. The figure shows the load distribution with a wheelchair ergometer seat located at 250 mm (A) and 135 mm (B) from the axis of the wheel

Conclusion and discussion

It was observed in this work an effective increase (p=0.004) in the load distribution by approaching the seat to the centre of the wheel axle in the maximum static propulsion effort of wheelchair users. Adjustments of the centre of gravity of wheelchair should consider distributing load in order to prevent secondary complications, improving comfort and mobility in a wheelchair.

Acknowledgements

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Clinical evaluation of hand-rim propulsion with power-assist wheels

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Abstract Shoulder injuries are common in hand-rim wheelchair users; to reduce upper extremity load during propulsion power-assist wheels are effective. Whether power-assist propulsion is also beneficial in daily situations is unclear. Therefore wheelchair skills and self-efficacy during hand-rim and power-assist hand-rim propulsion, and the subject's opinion about the power-assist wheels were investigated. Twelve experienced hand-rim wheelchair users tried the power-assist wheels for four weeks in their home environment. The 'Wheelchair Circuit Test' with additionally the 10 seconds and 3 meter wheelie, the 'Self-Efficacy in Wheeled Mobility Scale' and the Dutch version of the 'Quebec User Evaluation of Satisfaction with Assistive Technology' were completed. Between both wheels no significant changes were found on wheelchair skills and self-efficacy. Satisfaction with the device was 3.5 out of 5 points, with the lowest score on weight (2.4) and the highest score on effectiveness (3.9). Although increased ease of propulsion was reported, objective ratings showed no differences in wheelchair skills and self-efficacy. High work-capacity of the upper extremity, use of a hand-bike, and independent car transfers seem to have a negative influence on the usability of power-assist-wheels.

Keywords Power-assist propulsion, self-efficacy, wheelchair skills

Introduction

Hand-rim wheelchair users extensively rely on their upper extremities, not only for mobility but also for other activities of daily living like reaching and weight relief lifts (Van Drongelen, Van der Woude et al, 2005). If hand-rim propulsion is compromised for example by upper extremity injury or pain, insufficient arm strength or low cardio-pulmonary reserves, subjects are forced to another way of mobility. Subjects can be pushed by an assistant, shift to a powered wheelchair, use a scooter for outdoors or replace normal wheelchair wheels with power-assist wheels (Cooper, Boninger et al. 2006). Each of these options are effective in lowering the mechanical strain. The benefit of a power-assist wheelchair over the other options is that the biomechanical and physiological stress associated with self-propulsion decreases, while preserving the opportunity to exercise wheeling (Kloosterman, Snoek, et al. 2012) and stay active to some extent.

Within our project group (Active Assistive Devices research line of the MIAS (Major Innovations

for an Aging Society) project), we developed power-assist wheels with an additional function: with the small hub it is possible to drive completely powered (see fig). With this prototype power-assist wheels shoulder load during propulsion decreased significantly compared to propulsion without power-assist (Kloosterman, Eising et al. 2012). However, whether these prototypes were also beneficial in daily situations was unclear. Therefore we investigated wheelchair skills and self-efficacy during hand-rim and power-assist wheelchair propulsion in the personal environment and we asked a subject's opinion about the power-assist wheels.



Figure 1. The used power-assist wheelchair wheels. Large hand-rim for assisted propulsion, small hand-rim for completely powered propulsion.

Methods

Participants

Twelve hand-rim wheelchair users (six men) with a mean age of 38.6 ± 7.8 years participated in this study. The hand-rim wheelchair is their primary mode of mobility for 13.2 ± 9.1 years due to spinal cord injury (n=5; height T1, T5, T7, T9, T10), Ehlers Danlos (n=2), M. Strümpell (n=2), cerebral palsy (n=1), spastic diplegia (n=1), and Friedreich's ataxia (n=1).

Research protocol

The measurements were part of a larger randomized controlled trial. For the clinical evaluation there were two measurement conditions: own wheelchair frame with (1) normal hand-rim wheels and (2) power-assist wheels. After two weeks using one condition in the home environment, the Wheelchair Circuit Test (Kilkens, Dallmeijer, et al. 2004) was performed, additionally with a 10 seconds and 3 meter wheelie. After four weeks the 'Self-Efficacy in Wheeled Mobility Scale' (Fliess-Douer, Van der Woude, 2011) and the Dutch version of the 'Quebec User Evaluation of Satisfaction with Assistive Technology' (Wessels and De Witte. 2003) were completed.

Statistics

The differences between both conditions were determined with the Wilcoxon Signed Rank test, reporting the test statistic T (smallest of the two sum of ranks), significance (p), and effect size (r). The level of significance was set at $p<0.05$.

Results

Between both conditions no significant differences were found in the ability and the performance time score of the Circuit Test, performance of the 10s and 3m wheelie and in self-efficacy (respectively Wilcoxon Signed Rank test/significance level/effect size:2/.783/−.08, 2/.075/-.54, 0/.180/-.13, 4/.779/-.47 and 3/.609/-.148). Satisfaction with the power-assist wheels was 3.5 out of 5 points, with the lowest score on weight (2.4) and the highest score on effectiveness (3.9). Heavy weight was reported to lead to difficulties with car transfers, replacing wheels, public

transport and hand biking. The satisfaction on effectiveness resulted in subjects reporting less strain on the upper extremity, reduced shoulder pain, less energy cost, and no need to be pushed by an assistant.

Conclusion and discussion

Although increased ease of propulsion was reported, objective ratings showed no benefits in wheelchair skills and self-efficacy during power-assist hand-rim wheelchair propulsion. In the subjective evaluation high work-capacity of the upper extremity, use of a handbike and independent car transfers which required taking off and putting on the wheels, seem negative influencers for satisfaction with the power-assist-wheels.

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Ultrasound and kinetic changes in shoulder joint after two different workload settings in a treadmill

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Abstract Shoulder pain is a common problem for manual wheelchair users. The aim of this study was to examine the relationship between shoulder forces and moments with shoulder pathology using ultrasound images after propelling a manual wheelchair in two workload settings. Shoulder joint kinetics was recorded from 14 wheelchair manual users with spinal cord injury after a high and a low intensity wheelchair propulsion tests (constant and incremental). Shoulder joint forces and moments were calculated using inverse dynamic methods and shoulder pathology was analyzed using shoulder ultrasound images taken before and direct after the exercise. Shoulder joint kinetic changes were more remarkable after the more intensive task showing the significance of high intensity activity. Increases in medial peak shoulder force were correlated with increases in long axis biceps tendon thickness (LBTT) (rho= 0.594, $p<0.05$) and with decreases in subacromial space measured following Cholewinsk Index (rho= -0.534, $p<0.05$). More research is needed to collect clinical information and correlate shoulder pain data with ultrasound images and shoulder joint kinetic information.

Keywords Kinetics, shoulder joint, wheelchair propulsion, ultrasonography, spinal cord injury.

Introduction

Manual wheelchair users with spinal cord injury have a high prevalence of shoulder pain (Mercer, JL et al. 2006). Estimates of shoulder pain among manual wheelchair users with paraplegia ranges from 30% (Ballinger, D et al. 2000) to 73% (Pentland, WE et al. 1991). High mechanical shoulder stress accompanying the propulsion of manual wheelchairs facilitates overuse syndrome as one potential factor to develop shoulder pain in this population (Subbarao, J et al. 1995). A reasonable method to study the relation of the forces exerted on the shoulder and radiographic changes due to shoulder pathology could be to analyze different wheelchair propulsion tasks with different effort intensity that causes different levels of shoulder joint forces

(Koontz, AM et al. 2008; Desroches, G et al. 2008). The aim of this study was to calculate differences in shoulder joint forces and moments between early and late propulsion following two different wheelchair propulsion protocols (low and high intensity activities) and to determine if there is a relation between the increase of the shoulder joint forces after propelling a wheelchair and specific changes in shoulder ultrasound images.

Methods

Subjects

To be included in the study, subjects had to have had a traumatic SCI at level T2 or below AIS A or B, occurring more than 18 months before the star of the study and they had to use the wheelchair as the primary means of mobility.

Data collection

All subjects performed 2 different test of wheelchair exercise on a treadmill (Figure 1) were defined:

- A high intensity wheelchair propulsion test with incremental workload.
- A low intensity wheelchair propulsion test with constant workload.

The following variables were measured:

- Divergent validity variables: personal (gender, age, weight, height) and lesion (time since injury, level of injury) characteristics.
- A visual analog scale (VAS) and Weelchair User´s Shoulder Pain Index (WUSPI) was used to measure current pain.
- Ultrasound measures: The anatomical shoulder references and biceps and supraspinatus tendon characteristics.
- Biomechanical data: Peak shoulder forces and moments variables.

Statistics

Shapiro-Wilk test to calculate the differences in shoulder joint forces and moments was applied between both conditions. A Student t test for independent samples two-tailed analysis was applied for those variables that followed a normal distribution. Mann Whitney U test for independent samples was used for comparison of those variables that showed a nonparametric distribution ($p<0.05$).



Figure 1. Overview of the test setup where the subject is propelling against extra resistance by a pulley system including markers position.

Results

The increase in forces and moments were higher after high intensity wheelchair propulsion protocol. Considering high intensity task, statistical differences were found between early and late propulsion for all parameters analyzed but decreases adduction and abduction shoulder peak moments.The higher superior peak forces and the lower internal rotation peak moments were correlated with higher WUSPI values (rho= .648, *P*<.05 and rho= -.697, *P*<.05). Correlations were performed between shoulder joint kinetics and ultrasound images considering data obtained during early and late propulsion. Focusing on the correlations between changes in kinetic and ultrasound findings before and after the high intensity propulsion task, increases in medial peak shoulder force were correlated with increases in long axis biceps tendon thickness (LBTT) (rho= 0.594, p<0.05) and with decreases in subacromial space measured following Cholewinsk Index (rho= -0.534, p<0.05).

Conclusion

Shoulder joint forces and moments were increased when propelling a wheelchair in a more intensive task showing the significance of high intensity activity and high loads on shoulder pain development. However, no differences were found for the ultrasound images after high intensity wheelchair propulsion task. Acute changes in subacromial space, biceps and supraspinatus tendons ultrasound images were correlated with changes in anterior and medial peak shoulder forces after different manual wheelchair propulsion workload settings in wheelchair users with SCI. More research activities are needed to collect clinical information and correlate shoulder pain data with ultrasound images and kinetic information.

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Relationships between kinetic/temporal wheeling parameters and wheelchair skills

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Abstract *Purpose:* To determine the relationship between wheelchair skills measured by the Wheelchair Skills Test 4.1 (WST) and kinetic wheeling variables assessed using the SmartWheel Clinical Protocol (SCP) among manual wheelchair users. *Methods:* Adult (N=16) and paediatric (N=8) manual wheelchair users who had a congenital or traumatic spinal cord injury participated in this study. Mean age ± SD was 32.4 ± 10.3 and 14 ± 2.8 years for adult and paediatric groups, respectively.. The WST score was evaluated for all participants. SCP variables measured included average force, velocity, push frequency, mechanical effectiveness and average distance per push was calculated based on the data collected. Relationships between WST and SCP were determined using Pearson Product Moment Correlation. *Results:* Twenty-four participants were included: 16 adults and 8 youth (10-17 yrs). Self-selected ramp (R^2=0.58; p<0.0001), tile speed (R^2=0.27; p=0.005), push frequency for ramp (R^2=0.21; p=0.0002) as well as tile and ramp push length (R^2=0.16; p=0.05; R^2=0.29; p=0.01) significantly correlated with WST score. A sub-analysis found no difference in kinetic measures between those that could perform a wheelie and those that could not. *Discussion:* Our study showed that SCP's speed related variables correlated to some degree with WST, similar to Pradon et al (2012) who asked participants to wheel to their maximum speed. However, the SCP has been shown to be a more reliable measure (Lui, 2012). *Conclusions:* Self-selected wheeling speed and push frequency on ramp and tile as well as push frequency on ramp, all correlated to wheelchair skills score, significantly. These variables could be used to assist clinicians as a preliminary indicator of skill, however there is no replacement for the full assessment of skills which include wheelies, an important intermediate skill for completing higher level skills such as kerbs.

Keywords wheelchair propulsion, biomechanics, wheelchair skills, spinal cord injury, adults, children

Introduction

Two of the most studied methods of evaluating manual wheeling capacity that are used to assist clinicians and therapists in prescribing wheelchairs are: (1) the Wheelchair Skills Test (WST) from Dalhousie University, which assesses specific wheelchair skills and (2) a clinical protocol using an instrumented wheel that measures kinetic and temporal-spatial variables.[1] The WST 4.1 is a reliable measure for performance of skill (test-retest ICC=0.90), however it is less reliable for evaluating whether a skill is completed safely (test-retest ICC=0.25).[2] The WST has been used by researchers as an outcome measure of total skill, as well as a clinical tool to evaluate ability to perform individual skills in various adult populations [3,4] and in children.[5] Many studies have been published on the use of wheelchair skills assessments to evaluate an individual's capacity to propel and maneuver a manual wheelchair in different environmental conditions. [1,6-16] These

evaluation methods are modeled on activities of daily living. Not surprisingly, wheelchair skills have been shown to predict quality of life and community integration.[2] An important wheelchair skill that enables community participation is the 'wheelie', for example individuals who could perform a 30-s stationary wheelie were more likely to work.[2] The wheelie is a precursor to many other skills, however many community dwelling manual wheelchair users do not know how to perform a wheelie.[15]

In addition to the wheelchair skills tests that have gained popularity amongst researchers and clinicians, instrumented measurement wheels have been used by researchers and many rehabilitation centres to record kinetic and temporal-spatial data during wheeling[15,16] A couple of instrumented wheels have been developed with software that enables clinicians to obtain biomechanical information about how a client is wheeling (e.g., peak force applied to the push rim, push angle, speed, push frequency, and mechanical effectiveness (the ratio of force applied in a tangential direction to total applied force)). The SmartWheel Clinical Protocol (SCP) is used to evaluate kinetic and temporal-spatial properties while wheeling on three surfaces (tile, carpet, 5˚ ramp) for 10m or 10s (whichever occurs first) utilizing an instrumented wheel.[10] Lui et al. demonstrated that the SCP is a reliable measure, with inter-session reliability of a single trial for the four main biomechanical variables (average force, push frequency, push angle and velocity), ranging from 0.70-0.85. When 5 trials of the SCP were averaged, the reliability increased to 0.80-0.93. Trials performed on carpet or on a 5° ramp, increased the reliability to 0.90-0.98 and 0.97-0.98 respectively.[19]

Purpose

To determine the relationship between wheelchair skills measured by the Wheelchair Skills Test 4.1 (WST) and kinetic wheeling variables assessed using the SmartWheel Clinical Protocol (SCP) among manual wheelchair users.

Methods

Adult (N=16) and paediatric (N=8) manual wheelchair users who had a congenital or traumatic spinal cord injury participated in this study. Mean age ± SD was 32.4 ± 10.3 and 14 ± 2.8 years for adult and paediatric groups, respectively. The WST score was evaluated for all participants. SCP variables measured included average force, velocity, push frequency, mechanical effectiveness and average distance per push was calculated based on the data collected. Relationships between WST and SCP were determined using Pearson Product Moment Correlation.

Results

Twenty-four participants were included: 16 adults and 8 youth (10-17 yrs). Self-selected ramp (R^2=0.58; p<0.0001), tile speed (R^2=0.27; p=0.005), push frequency for ramp (R^2=0.21; p=0.0002) as well as tile and ramp push length (R^2=0.16; p=0.05; R^2=0.29; p=0.01) significantly correlated with WST score. A sub-analysis found no difference in kinetic measures between those that could perform a wheelie and those that could not.

Discussion

Our study showed that SCP's speed related variables correlated to some degree with WST, These findings are similar to Pradon et al. who showed that their test of *maximal wheeling speed* had a higher correlation (r=0.72, R^2= 0.51) with the WST score, compared to the *self-selected wheeling speed* (r=0.57, R^2= 0.31). Although the ramp wheeling trial does not require maximal effort, it does require a greater power output from the individual, which is more similar in intensity to the test of *maximal wheeling speed*. Interesting that push frequency mechanical effectiveness did not correlate at all despite the expectation that a someone who use less strokes are often considered more efficient propellers and would probably have more skill level.
If a clinician wanted to minimize the time spent on the SCP, using only the ramp component of the SCP could be feasible to administer in a clinical setting and may provide relevance to wheelchair skills.

Conclusions

Self-selected wheeling speed and push length on ramp and tile ramp push frequency could be used to assist clinicians as a preliminary indicator of skill, however there is no replacement for the full assessment of skills for functional daily living.

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Oral presentations
Wednesday, April 23, 2014

Keynote lecture 2: Prof. Dr. E. Otten

Balance and energetics during walking and running in impaired adapted sports

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Abstract The solutions we encounter in the field for walking and running in adapted sports are bounded by technological and biological constraints. It is worthwile to look into these constraints and see what they mean in terms of possibilities for the future.

Keywords balance energetics adapted sports

Introduction

As soon as a part or parts of the human legs are missing and replaced by some technological device, balance and energetics may become compromised. The intact human body has had millions of years of optimization as a functioning system and the way natural selection works, this is guaranteed to produce at least a locally optimized system. (Bates et al. 2013) Any replacement of parts is cutting through this functioning system. Now fortunately the human brain is very adaptive, and so some of the missing function can be regained by a clever use of motor control and a smart choice in design and tuning of the devices. In order to understand this well, we have to get back to what locomotion is about in the presence of gravity field. Then we have to look at the solutions found.

Stiffness and its control

Leg stiffness is an important variable in running and walking. In running, the contact time of the foot of the runner is shortened at increasing velocity. This has to do with the range of motion of the legs. Obviously, during stance time, the foot has to leave the ground when the leg is at its furthest backward movement. Since the contact time is only a half period of a mass-spring resonating system and since the mass is unchanged, the stiffness has to increase at a decreasing contact time. Note that this is the vertical leg stiffness, not the leg stiffness as such.

Obviously, the intact human leg is able to change its stiffness properties by neuromuscular control, but a prosthesis can not dot this with the technology we now encounter in the field. The intact human leg is able to match its impedance to obtain the optimal resonance frequency

(Farahat and Herr, 2010) and so a prosthesis will have to be matched accordingly for the conditions in which performance has to be delivered.

Moreover, another thing is still very different between blade springs and intact feet: the influence of the roll-over effect under the intact foot. Lipfet et al (2012) indicate that the travel of the center of pressure under the foot helps to increase the functional leg length, which is not present in blade springs. The only way to compensate for this is to physically increase the length of the blade spring, which may compromise balance.

Balance and its control

In below knee amputees, balance is compromised in walking due to a lack of the control of the center of pressure under the feet, which in its turn evokes controllable horizontal ground force components that help to maintain balance. The solution to that is the use of a wider gait, foot placement control and hip strategy. In this way both lateral and forward-backward control of ground forces is not really an issue, although still somewhat compromised. Presently a new device has been patented that allows for a better control of lateral balance (Otten, 2012). However in running, balance is completely different from that in walking. Most of the balance is achieved by foot placement and multi-joint coordination. Roll-over movements of an intact foot during running can be varied step by step to help keeping the balance, but that is not possible using blade springs.

Energetics

The energetics of amputees using blade springs is quite complex. Many discussions have been put forward on whether humans can walk faster using prostheses. Although Weyand and Bundle (2010) try to make a case in favor of this statement, a convincing case is made by Kram et al. (2010) to state that this is not possible given the data available at the moment.

Obviously, blade springs are unable to produce positive work in a complete shortening-lengthening cycle, while a sound lower leg can produce positive work. But it requires less effort to swing the blade forward, since the mass and moment of inertia are much lower than those of a sound leg. In principle mechanical energy is conserved, so it should not matter that it takes greater effort to move a lower leg forward, since the energy it takes will be returned in some way. However, at impact of the foot the difference in velocity between foot and road needs to be minimized and so the forward motion needs to be stopped also, which is done primarily by eccentric contraction of muscles, which absorbs energy. This is why a blade spring is more favorable than a biological lower leg in running.

In running, some of the energy produced comes from the shoulder muscles, since the arm movements are able to accelerate the center of mass away from to the center of pressure. In unilateral amputee runners, this evokes asymmetrical arm movements, since the energy loss during the stance phase on the blade needs to be compensated by an increased effort at the sound side. Consequently, the kinematics of the sound limb of a unilateral amputee is different from that of an intact athlete (Buckley, 1999). The fascinating conclusion is that the human brain is able to find solutions in situations that may not have been part of the selective pressure during its evolution.

Device Design

Many of the inspiring performances in impaired adapted running have been done by using carbon fibre prostheses. Their low weight, high strength and energy returning properties make them very well suited. There is only one limitation: carbon fibre is largely linear in its force-length relationship. With finite element modeling it can be shown that in any open construction (such as a C-shaped blade), that has a single point of contact with the ground, the shape of the prosthesis does not change this linear force-length relationship into a non-linear one. It may very well be that a progressively stiffer prosthesis would be more favorable for a wider variety of running speeds. And so a new design is called for to make this possible. Whether electronic control in running prostheses would be beneficial is very doubtful, since swing-time control can be done mechanically, while the production of power would make the prosthesis too heavy for running, based on the present battery technology available. Besides, it would create an unfair situation in competition, which is already quite complex in terms of classification.

The Future

Running and walking in impaired adapted sports keep triggering the imagination of a wider public, and that of scientists. It is a challenge to understand gait from a different perspective and to think about the boundaries of technology and our understanding of the adaptability of the human system. Most likely the future does not hold revolutionary changes in the devices used in impaired adapted sports, but more likely finds solutions in details like spring properties, alignment and designs that keep the human motor system in mind, since its adaptive power is formidable.

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Oral presentations
Wednesday, April 23, 2014

Session 3: Gait

C-Mill gait adaptability training in older adults after fall-related hip fracture: user`s perspective and training intensity

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Abstract This study aimed to evaluate the experience of older adults with a fall-related hip fracture with the novel concept of gait adaptability training on the C-Mill (an instrumented rehabilitation treadmill augmented with visual context, like obstacles and targets), and to compare the intensity of this training with conventional treadmill training and overground gait training. Fifty-seven older adults (83±7yrs) with a recent fall-related hip fracture were randomly allocated to 6 weeks of dose-matched C-Mill gait adaptability treadmill training (N=19), conventional treadmill training (N=19) or conventional overground gait training (N=19). Participant`s experience was evaluated after the training period with a purpose-designed questionnaire using a 10-point numerical rating scale. For the C-Mill and conventional treadmill groups, the intensity of training was defined as the average number of steps taken during the training sessions, as registered by the instrumented treadmill. The number of steps taken during one overground gait training was assessed manually by two online observers in a group of 38 representative older adults (81±7yrs) in a similar rehabilitation phase. All training groups rated the training as useful, motivating, fun, challenging and enjoyable (all median scores ≥ 7). Participants took significantly more steps during C-Mill training (814 [426-1175], median [min-max]) and conventional treadmill training (798 [417-1416]) compared to overground gait training (343 [90-1180], both $p<0.001$). These results suggest that C-Mill gait adaptability training is feasible and well accepted by older adults recovering from a fall-related hip fracture. Moreover, C-Mill training combines the increased intensity of treadmill walking (i.e., twice as many steps compared to overground gait training) with practicing gait adjustments to environmental context (an important fall-risk factor).

Keywords Older adults, hip fracture, gait adaptability, treadmill training, user`s perspective

Introduction

Conventional treadmill walking is a widely used form of gait training in various patient groups and is often commended for its intensity (i.e. the number of steps taken), although scientific evidence is scarce. Today, gait training programs increasingly use state-of-the-art technologies such as virtual and augmented reality, be it with or without a treadmill. The C-Mill is an innovative, instrumented treadmill augmented with visual context, which was specifically developed to practice the ability to adjust gait to environmental hazards. During C-Mill gait adaptability training,

gait adjustments are elicited by aligning foot placement relative to the visual context projected on the treadmill surface (i.e. obstacles and targets).

Older adults show reduced ability to make gait adjustments relative to environmental demands. Falls are also common in this population, with environmental hazards contributing to approximately half of all falls. C-Mill gait adaptability treadmill training might thus be beneficial for older adults. The attitude of (frail) older adults towards this kind of modern gait training is however unknown. This study aimed to evaluate the experience of older adults with a fall-related hip fracture with the novel concept of C-Mill gait adaptability training and to compare the intensity of this training with conventional treadmill training and overground gait training.

Methods

Participants

Fifty-seven older adults (age 83.0 ± 6.7 years) with a recent fall-related hip fracture were included from residential and rehabilitation centre Zorggroep Solis, Deventer. Participants in this study took part in an ongoing trial evaluating the efficacy of C-Mill gait adaptability treadmill training for improving walking ability and reducing fall incidence and fear of falling relative to conventional treadmill training and usual care (Van Ooijen, Roerdink, et al. 2013).

Protocol and outcome measures

Participants were randomly allocated to 6 weeks of dose-matched C-Mill gait adaptability treadmill training (N=19), conventional treadmill training (N=19) or conventional overground gait training (N=19). After the training period, participant`s experience with training was evaluated with a purpose-designed questionnaire regarding experienced usefulness, motivation, challenge, joy (rated on a 10-point numerical rating scale) and perceived discomfort. For the C-Mill and conventional treadmill groups, the intensity of training was defined as the average number of steps taken during the training sessions, as registered by the instrumented treadmill. The number of steps taken during one overground gait training was assessed manually by two online observers in a group of 38 representative older adults (81±7yrs) in a similar rehabilitation phase.

Statistics

Participant`s experience with training and the number of steps taken during training were compared between training groups using Kruskal-Wallis tests. Post-hoc analyses were performed using Mann-Whitney U tests. Perceived discomfort during and after training is reported using descriptive statistics. Results are reported as median (minimum – maximum).

Results

Forty-five participants (age 82.1 ± 6.7 years) completed the questionnaire after the training period. Eleven participants dropped out of the study due to transfer to another nursing home (n=2), early discharge home (n=5), illness (n=2), death (n=1) and experienced stress with participation (n=1). One participant did complete the training program but was unable to fill out the questionnaire due to cognitive problems.

All training groups rated the training as useful, motivating, fun, challenging and enjoyable (all median scores ≥ 7, Table 1). Participants were initially moderately reserved about C-Mill and conventional treadmill training. However, both training groups rated the training suitable for older adults and would recommend it to peers (all median scores = 8, Table 1). No significant differences in experience with the training were observed between training groups. Perceived

discomfort and complaints during and after training mainly comprised muscle soreness, fatigue, shortness of breath and painful joints, and were most frequently reported in the C-Mill training group, followed by the conventional treadmill training group and the overground training group (Table 1). However, more than half of the discomfort experienced by the C-Mill and conventional treadmill training groups were also experienced during the overground gait training sessions performed by these groups (Table 1). The number of steps taken during training differed significantly between training groups (X^2 = 30.6, p < 0.001). Participants took significantly more steps during C-Mill training (814 [426-1175]) and conventional treadmill training (798 [417-1416]) compared to overground gait training (343 [90-1180], U = 47 and 59 respectively, both p < 0.001).

Table 1. Participant`s experience with the three forms of gait training

	Conventional treadmill training (N=14)	**C-Mill gait adaptability treadmill training (N=13)**	**Overground gait training (N=18)**
Q1. Experienced usefulness of the training	8.5 (5-10)	8 (7-10)	8 (6-10)
Q2. Experienced motivation with the training	8.5 (3-10)	8 (7-10)	8 (5-10)
Q3. Experienced fun during training	7 (3-10)	8 (6-10)	8 (4-10)
Q4. Experienced level of challenge during training	7 (3-10)	8 (7-10)	7 (5-10)
Q4. Experienced level of enjoyment during training	7.5 (3-10)	8 (6-10)	8 (4-10)
Q5. Initial level of reservedness with training	6 (3-10)	6 (1-8)	
Q6. Experienced relevance of training for older adults	8 (3-10)	8 (7-10)	
Q7. Recommendable for peers	8 (3-10)	8 (7-10), N=12	
Number of participants experiencing discomfort during training, n (%)	8 (57)	9 (69)	7 (39)
Discomfort present during overground gait training, n	6	6	
Number of participants experiencing discomfort after training, n (%)	3 (21)	8 (62)	7 (39)
Discomfort present after overground gait training, n	2	4	

Conclusion and discussion

C-Mill gait adaptability training is feasible and well accepted by older adults recovering from a fall-related hip fracture. Moreover, C-Mill training combines the increased intensity of treadmill walking (i.e., twice as many steps compared to overground gait training) with practicing gait adjustments to environmental context (an important fall-risk factor), which improves the task-specificity of gait training. In the ongoing trial (van Ooijen, Roerdink, et al. 2013), we will examine the relative efficacy of the three forms of gait training on gait, fear of falling and actual falls.

Acknowledgements

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Muscle activity in the Lokomat: Effect of guidance and interactions with speed and body weight support

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Abstract The purpose of the present study was to determine the effects of movement guidance, and its interactions with gait speed and body weight support (BWS), on the neuromuscular control of robotic assisted walking. Ten healthy subjects walked in the Lokomat exoskeleton (Hocoma AG, Volketswil, Switzerland), while movement guidance (0, 50 or 100%), gait speed (0.8, 1.8 or 2.8 km/h) and BWS (0 or 50%) were varied systematically. Muscle activity of six muscles (Erector Spinae, Gluteus Medius, Vastus Lateralus, Biceps Femoris, Medial Gastrocnemius and Tibialis Anterior) was recorded by means of electromyography. The results showed that guidance provided by the exoskeleton led to phase-specific reductions of muscle activity, and that these effect were independent of gait speed or the amount of BWS provided. Thus, guidance caused local reductions in the amplitude of the patterns, but did not alter the gross temporal patterning of the muscle activity. In order to promote active participation of patients during training, high levels of guidance and BWS should be avoided and gait speed increased.

Keywords Electromyography; Robotics; Neurorehabilitation; Gait; Body Weight Support

Introduction

During robot assisted gait training (RAGT), actuated exo-skeletons can provide movement guidance to the lower extremities, and reduce the required effort for patients to actively move their limbs. As such, guidance alters the constraints under which neuromuscular control operates. To develop specialized training protocols for RAGT, it is essential to understand how movement guidance affects muscle activity. Because body weight support (BWS) and gait speed are also known to modulate muscle activity (Finch et al. 1991; Ivanenko et al. 2002; den Otter et al. 2004), the assessment of the effects of guidance on neuromuscular control should also address its interactions with speed and body unloading. Therefore, the present study determined the effects of guidance on gait related muscle activity during robotic assisted walking, and how these effects depend on gait speed and BWS.

Methods

Participants

Ten healthy subjects (6 females, mean age 20.9 +/- 2.2 yrs), that did not suffer from any disorder that is known to affect gait, balance or muscle activity, volunteered to participate in this study.

Research protocol

For this study, the Lokomat Pro version 6.0 (*Hocoma AG, Volketswil, Switserland*) was used for robotic assisted walking. Prior to the experiment, individual adjustments to the exoskeleton were made, based on participants' anthropometric characters.

Activity of six muscles was measured by means of electromyography: Erector Spinae (ES), Gluteus Medius (GM), Vastus Lateralus (VL), Biceps Femoris (BF), Medial Gastrocnemius (MG) and Tibialis Anterior (TA). To detect gait events (first double support (DS1), single support (SS), second double support (DS2) and swing (SW)), customized insoles containing pressure sensors were used.

Participants walked a total of 18 trails in the Lokomat, each trial representing a unique combination of guidance (0, 50 or 100%), BWS (0 or 50% of participants' body weight) and gait speed (0.8, 1.8 or 2.8 km/h).

Statistics

A series of three-way univariate repeated measures ANOVA's was used to test the effects of the factors Guidance, Speed and BWS and their mutual interactions, for four sub-phases of the gait cycle (DS1, SS, DS2, and SW), separately. All effects were evaluated using an alpha of 0.05.

Results

Step phase durations

The effect of guidance on DS1 duration depended on gait speed: At lower gait speeds the supply of guidance resulted in a shortening of the DS1 phase, whereas at higher speeds guidance led to a prolongation of DS1. Guidance did not affect the duration of other phases ($p>0.05$).

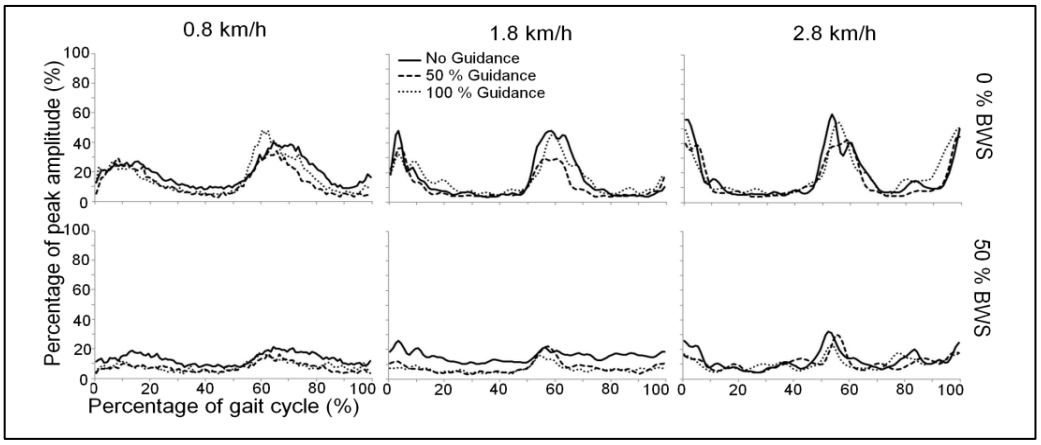

Figure 1. Average EMG profiles of the Erector Spinae of one participant, for each of the gait conditions walked in the Lokomat.

Muscle activity

Providing guidance to the legs did not alter the gross temporal patterning of muscle activity. However, as illustrated by the individual example depicted in figure 1, phase specific reductions of muscle activity were seen in four of the six muscle (ES, GM, BF, MG), mainly during the stance phase. Providing BWS also caused reductions in muscle activity (ES, GM, VL, TA, MG), while the amplitude of muscle activity increased with gait speed (GM, BF, VL, TA, MG).

The effect of guidance did not depend on the level of BWS or gait speed, although the MG did show slight attenuation of gait speed effects due to higher levels of guidance. Gait speed effects depended on BWS, as they were most prominent when BWS was provided (ES, MG).

Conclusion and discussion

Recently, research has shown that walking in the Lokomat exoskeleton (0% guidance) alters the muscular activity in terms of muscle amplitude, when compared to treadmill walking (van Kammen et al. submitted).The present study elaborates on this, indicating that, independent of BWS and gait speed, guidance provided by the Lokomat exoskeleton causes local rescaling of activity amplitude without changing the gross temporal patterns. The activity in muscles that are important for progression or stability (Perry, 1992) is reduced when guidance was provided, indicating that guidance helps to move the limbs (progression), while securing the limbs to prevent falling (stability). The two muscles that were not significantly affected by guidance were mostly active during weight acceptance (Perry, 1992), suggesting that this task was not assisted by the guidance that was provided.

Concerning the temporal structure of the stepping pattern, recent research showed that walking in the Lokomat exoskeleton (0%) alters the stance-swing ratio of walking by shortening the stance phase duration during slow walking (van Kammen et al. submitted). The present study shows that providing guidance at low speeds shortens the stance phase even more, but that this is normalized when gait speed is increased.

The present results suggest that, in order to prevent reductions in muscle amplitude and promote more active participation of the patient, high levels of guidance and BWS should be avoided. In addition, gait speed can be increased to promote normal stance-swing ratios and increased muscle activity.

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ATLET study – randomized trial of body-weight supported locomotor training in persons with SCI

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Abstract Body-weight supported locomotor training (BWSLT) is promoted as a rehabilitation tool for persons with incomplete Spinal Cord Injury (SCI). However, objective results from randomized clinical trials are lacking for persons with SCI in the chronic phase. The ATLET study is a single-blinded randomized clinical trial (RCT) to assess the effect of manual or robotic BWSLT on gait and ADL function in subjects with stable SCI. Thirty subjects with an incomplete SCI (American Spinal Injury Association grades AIS C and D) were planned recruited to each of the two study arms: 1) manual locomotor training and 2) robot assisted training. Within each study arm subjects were randomized to receive standard care or interventional training. The intervention groups received 60 training days of intensive BWSLT over 6 months. Both arms allow physical therapists to systematically train subjects to walk on a treadmill at increasing speed with increasing weight bearing. Evaluation of outcome is performed at another hospital by blinded evaluators using a standardized set of evaluation tools. Neurological injury level, gait, balance and quality of life are assessed. Post evaluation takes place 2-4 weeks after completing 60 days of training. The study is registered at ClinicalTrials.gov (#NCT00854555). Recruitment has proved challenging, and it was therefore necessary to modify design, allowing control patients, who had completed the control period, to join the intervention group after evaluation of the control period. So far, 15 patients have completed the control period and 17 the intervention period. Conducting a RCT in a setting with limited numbers of eligible cases is challenging despite vigorous recruiting campaigns and relatively good overview of the SCI population. This study will increase knowledge with regard to effects of two different modes of body-weight supported locomotion in the rehabilitation of chronic incomplete SCI.

Keywords Spinal Cord Injury, Locomotor training, Rehabilitation

Introduction

There are approximately 100 new cases of spinal cord injuries (SCI) each year in Norway. Loss of ability to walk and stand upright restricts independent mobility and autonomy of persons with Spinal Cord Injury and severely affects their quality of life. Recent research has shown promising results in terms of spinal cord recovery using Body-weight supported locomotor training (BWSLT), but there is a lack of randomized clinical trials among persons with SCI in the chronic phase (Berhman et. al 2006, Mehrholz et al. 2012). The hypotheses for this study is that persons with

motor incomplete SCI in the chronic phase through BWSLT, can regain, partially or completely, walking and/or standing ability and improve ADL function and QoL, which will have beneficial impact on estimated health care costs.

Methods

This is on-going single blinded, randomized study with two arms where patients with incomplete SCI are randomized to Study 1: BWSLT with robot assistance or control group and Study 2: BWSLT with manual assistance or control group.

Participants

Participants have been recruited from spinal care units and advertisement in the magazines for suitable patient organizations.

Inclusion

Inclusion criteria include: Motor incomplete SCI (grade AIS – C or –D), age 18-65 years, at least two years since time of injury, BMI <30, cognitively unaffected and motivated for BWSLT. If considered for study1, the patient must live within driving distance of Oslo (<70 km).

Exclusion

Exclusion criteria are: age under 18 or over 65 years, motor complete SCI grade AIS-A og –B, reduced cognitive function, BMI ≥30, spasticity and contractures which can impede BWSLT, change in spasm reducing medication during the study period, osteoporosis, pregnancy, physical limitations with respect to ability to use the robotic device, participation in other intensive training programs, other medical conditions which may interfere with the training protocol, previous knee- or hip replacement.

Intervention

Study 1 is conducted in an out-patient setting with three 60 minute training sessions per week for a total of 60 training days over a 6 month period.

Study 2 is conducted in an in-patient setting with 2 daily training sessions of 120 minutes total per day for a total of 60 days (3x4 weeks).



Figure 1.Iillustration of body-weight supported locomotor training with a robot (Lokomat) (Photo is provided by HOCOMA)

Evaluation

Evaluation of outcome measure is performed at a rehabilitation hospital by an evaluator blinded to the intervention and using a standardized set of evaluation tools. Neurological injury level, gait, balance and quality of life are assessed. Post evaluation takes place 2-4 weeks after completing 60 days of training.

Results

This is still an on-going study and the results are not yet available. Recruitment has proved challenging, and it was therefore necessary to modify design, allowing control patients, who had completed the control period, to join the intervention group after evaluation of the control period. So far, 15 patients have completed the control period and 17 the intervention period.

Conclusion and discussion

Conducting a RCT in a setting with a limited numbers of eligible cases is challenging despite vigorous recruiting campaigns and relatively good overview of the Norwegian SCI population. This study will increase knowledge with regard to the effects of two different rehabilitation modes of Body-weight supported locomotor training in the rehabilitation of chronic incomplete SCI

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Isometric muscle strength and its relation to gross motor tasks in children with cerebral palsy

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Abstract The aim of this study was to determine the extent of isometric strength impairments in children with cerebral palsy (CP) compared to typically developing peers (TD), and to describe the relationship with gross motor function tasks. Participants were 62 children with CP, who were able to walk without and with walking aids, and 47 TD children. Isometric muscle strength of the most affected or non-preferred leg was measured, and two walking ability tests and two gross motor tasks were performed. Isometric strength in children with CP was considerably reduced in children with CP, with increasing weakness in more affected children. KE and HA seems restrictive for walking ability and gross motor tasks in children with CP, but not in TD children.

Keywords Cerebral palsy, gross motor tasks, muscle strength, walking

Introduction

Children with cerebral palsy (CP) suffer from motor impairments, including spasticity and muscle weakness. To improve the capacity to perform daily activities like walking, treatment often targets at reducing spasticity and preventing muscle shortening. More recently the role of muscle strengthening in improving functional outcome is getting increasing attention (Scianni, Butler et al 2009). However, although several studies showed that muscle strength can be improved by systematic training, improved muscle strength has proven less effective as expected in improving walking ability and other daily activities. Most training studies used a more general training regime, that was not specifically targeted at muscle groups that could limit task performance (Scholtes, Dallmeijer, et al 2012). Insight in the association between strength of specific muscle groups and limitations in gross motor activities may help to design adequate training studies, and is expected to gain insight in whether muscle strength is the limiting factor for performing activities of daily living. The aim of this study was to assess the role of isometric strength of leg muscle groups in gross motor function tasks in children with CP compared to typically developing peers (TD).

Methods

Participants were 62 children with spastic CP, who were able to walk without (Gross Motor Function Classification System (GMFCS) I, n=32, and GMFCS II, n=20) and with (GMFCS III, n=10) walking aids (mean age 10.4±2.1 yrs) and 47 TD children (mean age 9.5±1.6 yrs). Age ranged from 6 to 13 years. All children with CP were measured at a special school for children with disabilities. The TD children were measured at an after school care location.

Isometric muscle strength was measured in the most affected or non-preferred leg, using a hand held dynamometer (MicroFet, Biometrics Almere The Netherlands) in knee extensors and flexors, hip flexors and abductors, and ankle plantar flexors. The 'make test' was performed, in which the child pushed against the dynamometer (MicroFet; Biometrics, Almere, the Netherlands) for 3s with maximal force exertion. All tests were performed according to standardized procedures. The mean scores of three tests were used for the analysis (Willemse, Brehm et al 2013).

Walking ability was assessed with the 1-min walk test. The child was instructed to walk around an oval track for 1 minute as fast as possible without running. Distance (in meters) was calculated to the nearest meter. The 10m walk test was performed to assess comfortable walking speed, calculated from from the time to walk 10m, while the child was instructed to walk at comfortable speed. The test was performed with a 'flying start' on a 14 meter straight, flat, smooth, non-slippery walking surface.

Gross motor activity was measured with two timed tests: the lateral step-up test and sit-to-stand test. The lateral step-up test assesses the number of step ups that the child can perform in 30 seconds on a 21 cm (GMFCS I and II) or an 11 cm (GMFCS III) step, with the most impaired leg on the step. The 30-s sit-to-stand test assesses the number of sit-to-stands that the child can perform in 30 seconds. The test was performed on a child-sized chair with a height adaptable seat (Scholtes, Dallmeijer 2008).

To assess the relationship between isometric strength and the walking and gross motor tasks, a multiple regression analysis, corrected for height, was applied with $p<0.05$. The walking test and timed test results were used as dependent variables, and isometric strength of the leg muscles was included in the models as determinants.

Results

As expected, isometric strength was considerably reduced in children with CP. Compared to values of TD children, knee extensors were reduced with 57-69%, knee flexors with 39-69%, hip flexors with 66-82%, hip abductors with 46-76%, and ankle plantar flexors with 39-54%.Values were lower in more severely affected children (i.e. higher GMFCS level).

Isometric strength of the hip abductors were significantly related to walking ability, measured by the 1-min walk test in children with CP (explained variance: $r^2=0.38$, $p<0.05$). The hip abductors and knee extensors were significantly related to comfortable walking speed, measured with the 10m walk test ($r^2=0.44$, $p<0.05$) in children with CP. There was no significant relationship between isometric strength and walking ability in TD children. Knee extensors and hip flexors were significantly related to the lateral-step-up test in children with CP ($r^2=0.40$, $p<0.05$), while there was no association in TD children. The hip abductors were related to sit-to-stand test results ($R^2=0.35$, $p<0.05$) in children with CP, and knee extensors and flexors were related to sit-to-stand test in TD children (0.34, $p<0.05$).

Conclusion and discussion

Isometric muscle strength is noticeably reduced in children with CP, with increasing weakness in more affected children. Knee extensors and hip abductors seem restrictive for walking ability and gross motor activities in children with CP, but not in TD children. Current finding are partially in agreement with earlier finding in this population (Ferland, Lepage et al 2012), and confirm that hip abductors and, to a lesser extent, knee extensors are important muscle groups in relation to walking ability. Interpretation of results is limited by lack of lever arm information of the isometric strength assessments. Joint moments could therefore not be calculated. Further research should also include hip extension strength and bilateral strength assessments to identify target muscle groups for strength training interventions in children with CP.

Acknowledgements

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Oral presentations
Wednesday, April 23, 2014

Session 4: Prosthetic Walking

The Shank-to-Vertical-Angle as a control parameter for tuning Ankle-Foot Orthoses

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Abstract Tuning of Ankle-Foot Orthoses (AFOs) is necessary to maximize normalization of gait kinematics and kinetics in children with Cerebral Palsy. Tuning is the adjustment of an AFO-footwear combination (AFO-FC) to align the Ground Reaction Force (GRF) with respect to the joint rotation centers and is often described by the Shank-to-Vertical-Angle (SVA). This study aims to investigate whether the SVA can be manipulated to align the GRF during walking and, subsequently could serve as a control parameter for tuning AFOs. Ten healthy subjects participated in the study, of which a preliminary dataset of five subjects (2 men) is presented in this abstract. Subjects walked at comfortable speed on an instrumented dual-belt treadmill, while 3D kinematic and kinetic data were processed in real-time. Subjects performed six trials while walking with bilateral rigid AFOs, immobilizing the ankle joint. AFO-FC heel height was manipulated using three wedges of different heights, aiming to impose an SVA of 5°, 11° or 20°, each combined with a flexible or stiff footplate. The SVA, as well as hip, knee and ankle angles and net joint moments of the right leg during midstance were determined and averaged over the gait cycles. The mean SVA significantly increased with increasing heel height ($p=0.02$), while no effect of footplate stiffness was found ($p = 0.89$). In concert with the change in SVA, the knee flexion angle and internal knee extensor moment also increased significantly with increasing heel height ($p=0.005$ and $p=0.003$ resp.). Although the stiff footplate tended to inhibit this effect, no significant effects of footplate stiffness or interaction effect of heel height and footplate stiffness were found ($p>0.05$). Effects of heel height and footplate on the hip and ankle kinematics and kinetics were limited. Our results show that in healthy adult subjects walking with bilateral rigid AFOs, the SVA is responsive to changes in heel height and reflects concomitant changes in the sagittal knee joint angle and net moment. The SVA seems not responsive to changes in footplate stiffness. Our results support the use of SVA as a control parameter during the tuning process of AFOs.

Keywords Cerebral Palsy, gait, joint kinematics and kinetics, Ankle Foot Orthosis, tuning

Introduction

In children with Spastic Cerebral Palsy symptoms as spasticity and muscle weakness often cause gait deviations. Ankle-Foot Orthoses (AFOs) aim to intervene in these gait deviations by normalizing joint kinematics and kinetics (Buckon, Thomas et al., 2004, Brehm, Harlaar et al., 2008). Although studies indicate that AFOs can improve gait, adequate tuning of the AFO to align the Ground Reaction Force (GRF) with respect to the joints may optimize the effectiveness (Morris, Bowers et al., 2011). The alignment of an AFO Footwear Combination (AFO-FC) is often

quantified in terms of the Shank-to-Vertical-Angle (SVA), which is the angle of the shank relative to the vertical (Owen, 2010). Although several studies describe an improvement in gait following tuning of the AFO-FC based on the SVA, quantitative data on the effects of tuning on joint kinematics and kinetics is lacking (Eddison, Chockalingam, 2013). Therefore, this study aims to investigate whether the SVA can be manipulated to align the GRF during walking and subsequently, could serve as a control parameter for tuning AFO-FCs.

Methods

A total of ten healthy subjects participated in the study. A preliminary dataset of five subjects (2 men; mean (SD) age: 23 (2) years; mean (SD) BMI: 22 (3)) is presented in this abstract.

Protocol

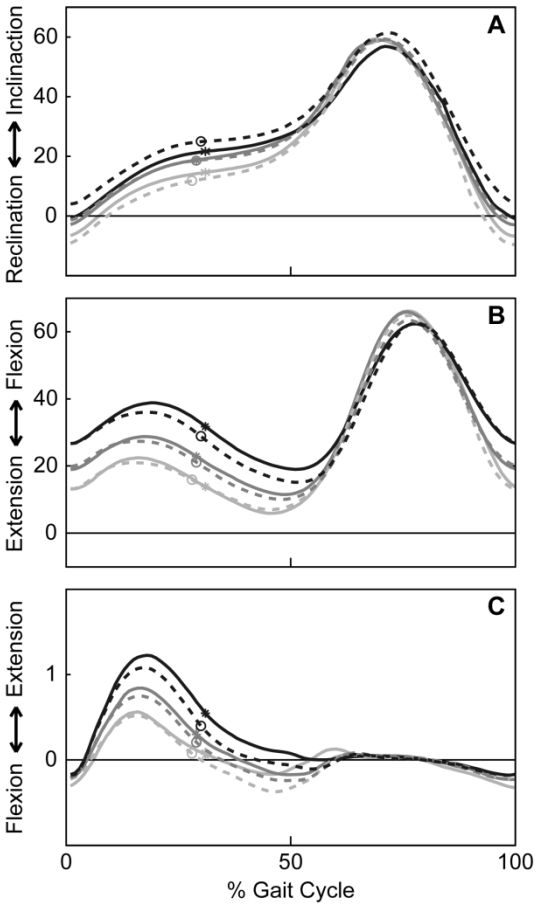
Subjects walked on a split-belt instrumented treadmill (GRAIL, Motek Medical BV, the Netherlands), while kinematic marker data were collected via a passive marker motion capture system (Vicon, Oxford, UK). Ground reaction forces were captured from force sensors mounted underneath both treadmill belts and synchronized with kinematic marker data at 120 Hz. The subjects were provided with bilateral rigid dorsal shelf AFOs and accompanying shoes (i.e. simple sneakers). They performed six trials at comfortable speed, while the AFO-FC heel height was manipulated with three insole wedges, combined with either a flexible or stiff footplate.

Materials and manipulations

The rigid AFOs aimed to immobilize the ankle joint in a neutral angle of 0°. Increasing the heel height by applying insole wedges of 0.6 cm (low), 2.8 cm (medium) and 4.9 cm (high) resulted in manipulation of the SVA in a static position of 5°, 11° and 20° respectively. A stiff inlay footplate could be added to the AFO's original flexible footplate as a second manipulation to the AFO-FC.

Data processing

Marker and force plate data were low pass filtered at 6 Hz. Using the Human Body Model (van den Bogert, Geijtenbeek et al., 2013), sagittal hip, knee and ankle joint kinematics and kinetics were calculated in real-time using the D-Flow software (Geijtenbeek T, Steenbrink Fet al.,2011). Two markers were added to the model to calculate the SVA: one at a distal point on the tibia and one at the tuberositas tibiae. The SVA was determined as the inclination angle of the line connecting these two markers, relative to the vertical in the sagittal plane. The last 25 strides recorded with foot placement on a single belt were analyzed. The SVA and sagittal hip, knee and ankle angles and net joint moments of the right leg were



determined at midstance, which was defined as the moment that the malleolus marker of the contralateral leg passed the malleolus marker of the ipsilateral leg.

Statistics

The effects of the AFO-FC manipulations on SVA and joint kinematics and kinetics were analyzed using a repeated measures analysis of variance (ANOVA) with two factors (i.e. heel height and footplate stiffness) using Bonferonni adjustments (α=5%).

Results

The SVA in midstance significantly increased (p = 0.02) with increasing heel height (see Figure 1A) (mean (SE): 13.6° (1.4), 18.6° (1.8) and 23.1° (2.9) for low, medium and high heel height resp.), with a significant difference observed between the low and high heel height (p=0.03). Footplate stiffness did not affect the SVA in midstance (mean (SE): 18.6° (1.9), 18.4° (0.9) for flexible and stiff footplate resp. (p = 0.89)) and also no interaction effect between heel height and footplate stiffness was found (p=0.69).

Regarding joint kinematics and kinetics, manipulations of the AFO-FC mostly affected the knee (see Table 1), as the knee flexion angle and internal knee extensor moment significantly increased with increasing heel height (p=0.005 and p=0.003 resp.) (see Table 1 and Figure 1B-C). Although the stiff footplate tended to inhibit both knee flexion angle and internal extensor moment, no significant effect of footplate stiffness (p=0.14 and p=0.06 for angle and net moment resp.), nor an interaction effect of footplate stiffness with heel height was found (p=0.32 and p=0.51 for angle and net moment resp.). Ankle and hip angles and net moments also increased with increasing heel height (see Table 1), though only significant for joint angles. Furthermore, neither an effect of footplate stiffness nor an interaction effect was found.

Table 1. Joint flexion angles and internal extensor moments in midstance for different AFO-FC manipulations (N=5) (*mean (SE)).*

			Heel height				**Footplate stiffness**	
			Low	**Medium**	**High**	**Post hoc**	**Flexible**	**Stiff**
Ankle	Angle	[°]	8.0 (2.9)	10.2 (3.2)	15.7 (3.9)	l-h; m-h	11.3 (3.7)	11.3 (2.9)
	Moment	[Nm·kg^{-1}]	0.64 (0.08)	0.82 (0.12)	1.02 (0.13)		0.71 (0.11)	0.94 (0.09)
Knee	Angle	[°]	17.0 (1.7)	22.9 (1.6)	31.5 (3.8)	l-m;l-h	24.9 (2.7)	22.7 (2.1)
	Moment	[Nm·kg^{-1}]	0.12 (0.06)	0.30 (0.06)	0.55 (0.09)	l-h	0.37 (0.05)	0.27 (0.07)
Hip	Angle	[°]	13.6 (5.0)	16.4 (5.4)	18.1 (4.9)	l-m;l-h	16.9 (5.1)	15.2 (5.2)
	Moment	[Nm·kg^{-1}]	0.02 (0.08)	0.04 (0.04)	0.06 (0.05)		0.04 (0.07)	0.04 (0.04)

l, m and h represent low, medium and high heel height respectively. No significant differences were found for footplate stiffness

Conclusion

In healthy young adults walking with bilateral rigid AFOs, the SVA seems responsive to changes in heel height, and reflects concomitant changes in sagittal knee kinematics and kinetics in

midstance. The SVA seems less responsive to changes in footplate stiffness. Hence, our results support the use of SVA as a control parameter during the AFO-FC tuning process.

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Functional analysis of a hydraulic prosthetic foot in trans-femoral amputees walking on level and inclined ground

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Abstract State of the art prosthetic components aim to help persons with trans-femoral amputation (TFA) to overcome obstacles like stairs and ramps. In this study TFA were monitored using conventional clinical gait analysis while walking on level ground, ascending and descending three different ramps with an angle of 2.5°, 5° and 7.5°. Six TFA were provided with a Kinterra prosthetic foot, which contains a hydraulic ankle joint, and a Plié II knee joint (both devices Freedom Innovations, USA). Prosthetic foot motion was calculated by means of a customized kinematic model. Data of 17 unimpaired subjects (RS) served as reference. RS showed an increase in peak dorsiflexion of 4.4°, in relation to level walking for ascending the 7.5° ramp, while TFA peak dorsiflexion in hydraulic ankle angle increases by 0.7°. Thus a larger dorsiflexion ROM of the hydraulic ankle would be desirable. In RS descending ramps adaptation to the decline is accomplished by an increased knee flexion in terminal stance. For TFA descending ramps involved side flexed knee (FK) and extended knee (EK) strategy were observed. In EK strategy the prosthetic foot partly adopts the adaptation to the incline by a larger peak plantarflexion in total prosthetic foot angle of 14.9° (N=1) compared to 11.9°±1.4° (N=4) in FK strategy. In further measurements a conventional prosthetic foot should be included to identify how the hydraulic ankle interacts with the prosthetic knee.

Keywords trans-femoral amputees, prosthetic foot, hydraulic ankle, ramp ascent, ramp descent, walking on inclines

Introduction

Individuals with trans-femoral amputation (TFA) have to overcome obstacles like stairs and ramps, to move freely within environment and participate in society. Over the last decades the design of prosthetic components aims to help TFA to improve in negotiating such barriers. The main focus for above knee prostheses was on the development of intelligent prosthetic knees. For TFA descending ramps and stairs such prosthetic knees modulate joint stiffness to provide the necessary support during the weight bearing phase. Thus the TFA can flex the prosthetic knee in stance while descending a ramp. Prosthetic feet design evolved as well. The Proprio Foot (Össur, Iceland) adapts actively to inclines (Fradet, Alimusaj et al. 2010). Also passive prosthetic feet aim to adapt to inclined surfaces via hydraulic ankle joints. In this pilot study unilateral TFA were observed when walking with a prosthesis consisting of a Kinterra prosthetic foot with a hydraulic ankle joint and a microprocessor controlled Plié II knee joint (both devices Freedom Innovations, USA). The proclaimed adaptability of this combination might lead to an adequate solution for both level and incline walking.

Methods

Six TFA (all men / 45±11y; 178±8cm; 82±15kg) were provided with a Plié II knee and a Kinterra foot using their current socket. All subjects were given four weeks time to adapt to the new prosthesis prior to data collection. TFA were monitored using a 12 camera system (Vicon, UK) while walking on level ground as well as ascending and descending ramps with an angle of 2.5°, 5° and 7.5°. Ground reaction forces were collected by two force-plates (Kistler, Switzerland). Kinematics and kinetics were calculated using Plugin Gait (Vicon, UK). One marker on the pylon (Fig. 1/A, 1), wand markers on the distal part of the hydraulic ankle (Fig. 1/A, 2) and markers on the shoe were used for calculation of the hydraulic angle (Fig. 1/B) and the total foot angle (Fig. 1/C). Results of the customized kinematic model had to be excluded for one TFA, due to technical issues during data collection. The hydraulic ankle of Kinterra offers approximately 2° of dorsiflexion range of motion (ROM) and 10° of plantarflexion ROM, depending on the alignment of the prosthesis and the effective heel height of the shoe wear. Gait data of 17 unimpaired subjects (RS / 28±6y; 178±8cm; 73±14kg) served as reference.

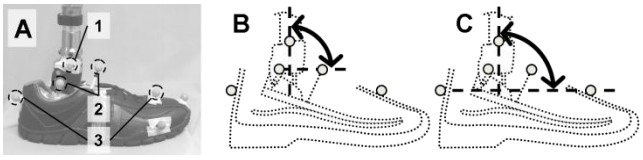

Figure 1. Marker placement of hydraulic ankle prosthetic foot with the according parameters (A,1:proximal pylon marker; A,2:wand markers on the distal part of the hydraulic ankle A,3:heel and toe markers; B: hydraulic angle C: total foot angle

Results

Level ground

TFA Mean peak plantarflexion in early stance was higher compared to RS and peak dorsiflexion was similar to RS. Mean hydraulic ankle ROM was 4.5°±0.8° and total foot angle ROM was 23.8°±2.1°. For level walking TFA show a peak hydraulic angle in stance of 2.8°±0.6°.

Ramp ascent

For level walking RS showed a peak dorsiflexion in stance of 13.9°±4.1°. During ramp ascent peak dorsiflexion in RS increased in relation to level ground by 1.7° for the 2.5° ramp, by 2.6° for the 5° ramp and by 4.4° for the 7.5° ramp. TFA mean peak hydraulic angle in stance increased in ramp ascend compared to level ground by 0.3° for the 2.5°, by 0.4° for the 5° and by 0.7° for the 7.5° ramp.

Ramp descent

The RS adapted to the decline with an increased knee flexion in terminal-stance (Fig 2; row A). TFA descending ramps showed two strategies, a flexed knee (FK) and an extended knee (EK) strategy (Fig 2; row A). For the 2.5° ramp one TFA, for the 5° ramp two TFA and for the 7.5° ramp four TFA out of six employed the FK strategy. In TFA with EK strategy the prosthetic foot was generally more plantarflexed in the first half of stance when compared to TFA with FK (Fig 2; row B; 7.5° descent EK). For the 7.5° ramp peak plantarflexion in stance was 11.9°±1.4° for TFA with FK strategy (N=4) vs. 14.9° for TFA with EK strategy (N=1).

Conclusion and discussion

Level ground

The Kinterra's hydraulic ankle shows only little ROM with 4.5° ± 0.8°, when compared to the total foot angle ROM of 23.8°±2.1°. The hydraulic ankles posterior shifted center of rotation and the associated change in leverage is probably the reason for this effect. In unimpaired subjects the hind foot lever induces an external plantarflexing moment in early stance. The shorter hind foot lever of the Kinterra results in a reduced external plantarflexing moment, which induces only little hydraulic ankle plantarflexion. However, a functional plantarflexion in early stance is present and accomplished in particular by deformation of the carbon fiber hind foot element.

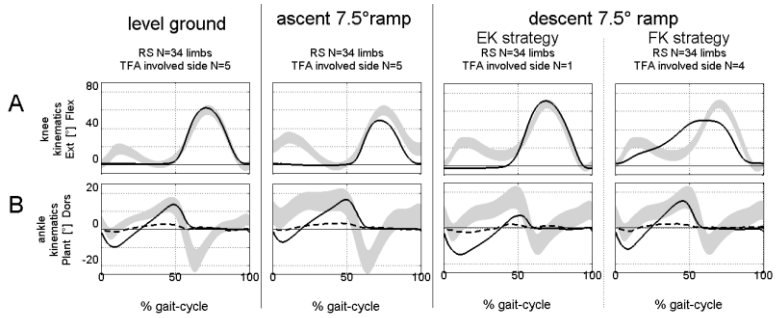

Figure 2. Knee and ankle kinematics for level ground, ramp ascent and descent (EK and FK strategy) exemplarily for the 7.5° degree ramp (row A&B: grey band = RS [results of Plugin Gait]; row A: ____solid black line TFA involved side knee kinematics; row B: ____solid black line TFA involved side total foot angle / ---- dashed black line TFA involved side hydraulic angle.

Ramp ascent

As in level ground walking, the hydraulic ankle shows only little ROM. For ramp ascent a larger dorsiflexion ROM of the hydraulic ankle would be desirable, as the ankle should be the adapting joint in this condition, as proposed by Hansen et al. (Hansen, Childress et al. 2004).

Ramp descent

Hansen et al. recognized the knee as the adapting joint for ramp descent (Hansen, Childress et al. 2004). However, in TFA both FK and EK strategies are utilized to descent the ramps. In EK strategy the prosthetic foot adapts to the incline by a larger peak plantarflexion of total foot angle compared to FK strategy. The variable strategies for TFA might be influenced by personal preferences of the user, but also by technical characteristics of the prosthetic knee and foot and their effects on the user. One could argue that modification of ankle-foot-complex stiffness influences external knee moments and therefore the choice of EK and FK strategy. For ramp descent reduced forefoot stiffness in combination with enhanced hind foot stiffness could promote knee flexion via an external flexing knee moment. In further measurements a conventional prosthetic foot should be included to identify how the hydraulic ankle interacts with the prosthetic knee.

Acknowledgments / Conflict of interest

We would like to thank Freedom Innovations for the financial support of this work.

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Effects of external stabilization on energy cost of walking in lower limb amputees

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Abstract The purpose of this study was to investigate whether impaired balance control is (partly) responsible for the increased energy cost of walking in lower limb amputees, by evaluating the effect of external lateral stabilization on the energy cost of walking. Based on previous studies we hypothesized that stabilization would reduce step width and the energy cost of walking, and that this decrease would be larger for amputees than for able bodied controls. Fifteen transtibial (TT) and 12 transfemoral amputees (TF), and 15 able bodied controls (CO) walked on a treadmill with and without external lateral stabilization. The effect of this manipulation on energy cost ($J \cdot kg^{-1} \cdot m^{-1}$), mean and variability of step width, and medio-lateral pelvic displacement were assessed between groups. No significant main effect of external stabilization on energy cost were found, although on average CO and TT showed a decrease in cost (-3% and -5% respectively), while TF showed an increase in cost (+4%) with stabilization. Step width, step width variability, and medio-lateral pelvic displacement decreased significantly with stabilization in all groups. While the limited effects of sideward stabilization on the energy cost of amputee walking might suggest that balance control is a minor issue in amputee gait, the counter-productivity of this manipulation in TF seems to indicate that sideward stabilization does have unwanted side-effects on walking energetics. We speculate that restraining the motion of the pelvis impedes movement adaptations necessary when walking with a (transfemoral) prosthesis, negating any beneficial effects with respect to balance control. The exact nature of these side-effects and the real contribution of balance control to the energy cost of amputee gait remain to be resolved.

Keywords gait, amputees, energy cost, balance control

Introduction

Walking ability in lower limb amputees is often hampered by a significant increase in the metabolic cost of walking (Waters et al. 1976). Previous research has been unable to fully explain this increase through impairments and compensatory strategies related to the forward progression of the body. Possibly, impairments in balance control, and strategies to compensate for these impairments could play a role in the increased cost of walking.

Lower limb amputees walk with wider steps and more variable step width, which can be seen as a strategy to ensure balance control in the medio-lateral direction (Hof et al. 2007; Hak et al. 2013). However, increasing step width and step width variability comes with a metabolic cost

(Donelan et al. 2001; O'Connor et al. 2012). To examine this cost for balance control, Donelan et al (2004) used a set-up to externally stabilize subjects in the medio-lateral direction. This resulted in a reduced step width and step width variability, as well as a reduced energy cost of walking in healthy subjects (Donelan et al. 2004). The aim of this study was to compare the effect of external lateral stabilization in lower limb amputees and able-bodied controls. We expected larger positive effects of external stabilization in amputees.

Methods

Participants

Fifteen transtibial amputees (age 58.8±12.7 yrs), 12 transfemoral amputees (age 54.8±13.0 yrs) and 15 able-bodied controls (age 56.7±12.4 yrs) participated in this study. All amputees were community ambulators who had completed their rehabilitation period. All subjects were able to walk for 5 minutes on a treadmill.

Protocol

The study protocol consisted of walking on a treadmill 1) without stabilization and 2) with external lateral stabilization. The external lateral stabilization was provided via spring like cords (spring stiffness 1260 $N.m^{-1}$) attached to a frame worn around the pelvis (fig. 1). The set-up was constructed in a way that subjects allowed normal arm swing, and minimized vertical or fore-aft forces of the springs. Subjects first performed practice trials of both experimental conditions to allow familiarization with the experimental procedures.

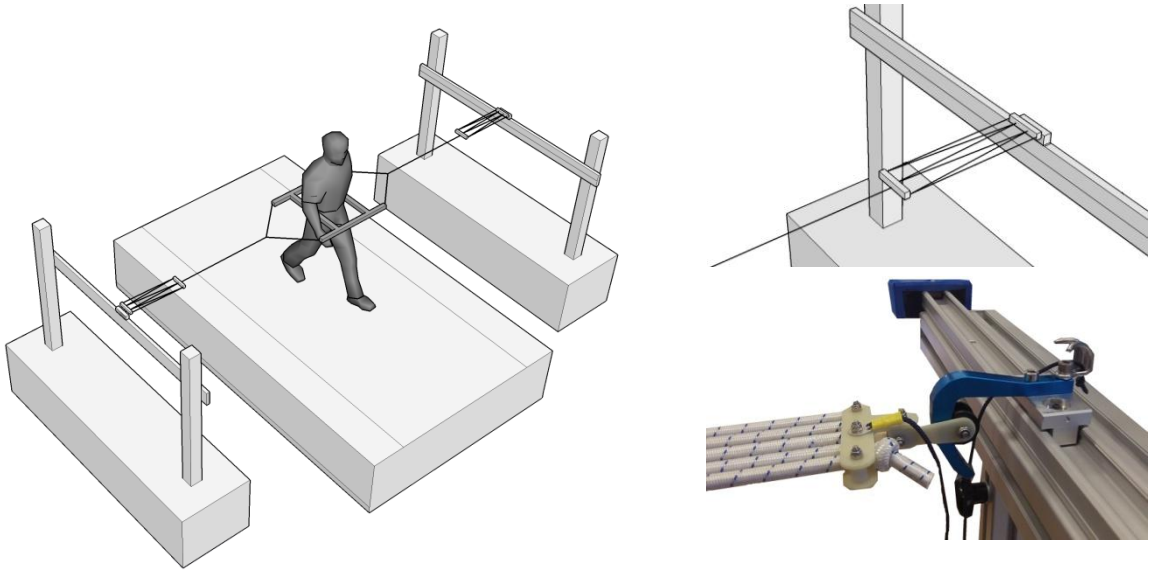

Figure 1. Experimental set-up. A) Schematic representation of experimental set-up. B) Inset of the elastic cords. C) Photo of the actual cords.

Equipment

The energy cost of walking ($J \cdot kg^{-1} \cdot m^{-1}$), was calculated from breath by breath oxygen consumption measured via a gas analyzer system (Quark b^2, Cosmed, Italy). Kinematic parameters (step width, step width variability, and medio-lateral pelvic displacement) were calculated from optoelectronic markers attached to the heels of the feet and the four corners of the frame attached to the pelvis (Optotrak, Northern Digital Inc., Waterloo, Canada).

Statistical analysis

A mixed ANOVA with condition [Normal, Stabilized] as within-subjects factor and group [CO, TT, TF] as between-subjects factor was used to identify significant group × condition interactions.

Results

No significant interaction was found in the effect of stabilization on energy cost for the three groups (p=.307), although CO (-3%) and TT (-5%) on average showed a decrease in cost, while TF (+4%) surprisingly showed an increase in cost on average. Stepwidth, stepwidth variability and medio-lateral pelvic displacement decreased in all groups. The decrease in stepwidth was significantly larger for TT than for CO and TF (p<.05).

Conclusion and discussion

In contrast to our expectations, external stabilization did not result in a significantly larger decrease in the energy cost of walking for amputees than for able-bodied subjects. On the contrary, for transfemoral amputees the energy cost of walking even tended to increase with stabilization. We speculate that restraining the medio-lateral motion of the pelvis impedes movement adaptations necessary when walking with a (transfemoral) prosthesis, negating any beneficial effects with respect to balance control. The stabilization method in its current form thus may not be a valid tool to study the influence of balance control on the energy cost of walking in amputees. This study highlights the importance of pelvic motion in amputee gait.

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Step length asymmetry in transtibial amputees; a strategy to regulate the backward margin of stability?

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Abstract The aim of this study was to characterize differences in step length, foot forward placement (FFP) and the concomitant difference in the backward margin of stability (BW MoS), between prosthetic and non-prosthetic steps of people after transtibial amputation. Ten people after transtibial amputation walked for 4 minutes on a self-paced treadmill. Step length and FFP were calculated at initial contact. The size of the BW MoS was calculated for the moment of initial contact and at the end of the double-support phase. Step length and FFP were shorter for the non-prosthetic step than for the prosthetic step. The BW MoS at initial contact was larger for the non-prosthetic step, but at the end of the double-support phase the BW MoS did not differ significantly between the prosthetic and non-prosthetic step. The latter appeared to be caused by a decrease of the velocity of the centre of mass (vCoM) during the double support phase following the non-prosthetic step. The smaller step length and FFP of the non-prosthetic step help to create a larger BW MoS at initial contact for the non-prosthetic step compared to the prosthetic step. Step length asymmetry in people after transtibial amputation might hence be seen as a functional compensation to preserve BW MoS during double support to cope with the limited push off power of the prosthetic ankle.

Keywords Amputees, Step length, Asymmetry, Margins of stability

Introduction

One of the characteristics of the gait pattern of people after transtibial amputation, is an asymmetry in step length. However, although asymmetry may be detrimental from a cosmetic perspective, there is no evidence that step length asymmetry is necessarily detrimental from a functional point of view (Winter et al., 1988). In fact, a shorter non-prosthetic step could be beneficial. An advantage of a smaller non-prosthetic step length, and specifically foot forward placement (FFP), might be that it will bring the center of mass closer to the base of support of the leading foot, and therefore increases the backward margin of stability (BW MoS) at initial contact (Espy et al., 2010; figure 1). A larger BW MoS implies that it is easier for the centre of mass (CoM) to pass the posterior border of the base of support (BoS) defined by the new stance leg, during the following single support phase and will decrease the risk of a backward loss of

balance. For lower limb amputees, a larger BW MoS at initial contact of the non-prosthetic step might be beneficial, because the push-off capacity of the prosthetic leg is reduced, which might limit the forward progression of the CoM during walking. The purpose of this observational study was to characterize differences in step length and FFP, between prosthetic and non-prosthetic steps of people after transtibial amputation and to test whether these differences comply with strategy to preserve sufficient BW MoS during walking .

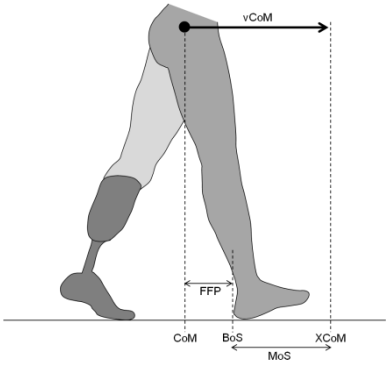

Figure 1: Schematic representation of the definition of the backward margin of stability (BW MoS) and foot forward placement (FFP) for the non-prosthetic step. The BW MoS is defined as the distance in BW direction between the extrapolated center of mass (XCoM and the dorsal border of the base of support (BoS) of the leading foot. The XCoM is calculated as the position of the center of mass (CoM) plus its velocity (vCoM) times a factor $\sqrt{(l/g)}$, with l being the length of the pendulum (for which often the leg length is used) and g the acceleration of gravity. The BW MoS can be increased by decreasing FFP or by increasing vCoM.

Methods

Subjects

Ten adult subjects with a unilateral transtibial prosthesis participated in this observational study.

Protocol

Before the experimental trial, subjects performed 5 warming-up trials of 3 minutes each to become familiar with walking on a (self-paced) treadmill and the virtual environment (CAREN, Motek Medical, BV). The experimental trial consisted of 4 minutes walking at self-paced walking speed.

Data collection and analysis

The speed of the treadmill was recorded and kinematic data of markers attached at the lateral malleoli of the ankles, the pelvis (left and right anterior superior iliac spines, and left and right posterior superior iliac spines) were collected with the Vicon system. Based on these data step length and FFP were determined at initial contact and the forward velocity of the CoM (vCoM) and the BW MoS were calculated at initial contact and at contra-lateral toe off (figure 1).

Statistics

To test whether differences between legs (non-prosthetic and prosthetic) in step length and FFP were significant, paired samples t-tests were used. To investigate whether BW MoS differed between prosthetic and non-prosthetic steps (factor: leg) and whether these variables changed during double support, i.e. between initial contact and toe-off of the contra lateral foot (factor: gait event), 2 x 2 factorial ANOVAs were performed.

Results

Step length (5.4%;p=0.030) and FFP (7.9%;p=0.015) were shorter for the non-prosthetic step than for the prosthetic step (figure 2). The BW MoS at initial contact was larger for the non-prosthetic step (p=0.007), but because of a significant leg by gait event interaction effect (p=0.008) MoS did not differ significantly at the end of the double-support phase (figure 3, upper panel).The latter was caused by a decrease in vCoM during the double support phase after the

non-prosthetic step (p=0.005), while vCoM remained constant during the double support phase after the prosthetic step (p=0.680) (figure 3, lower panel).

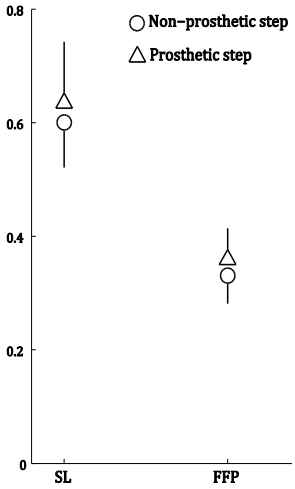

Figure 2: The average and between subjects standard deviation (n=10) of the prosthetic (O) and non-prosthetic (Δ) step length (SL) and foot forward placement (FFP).

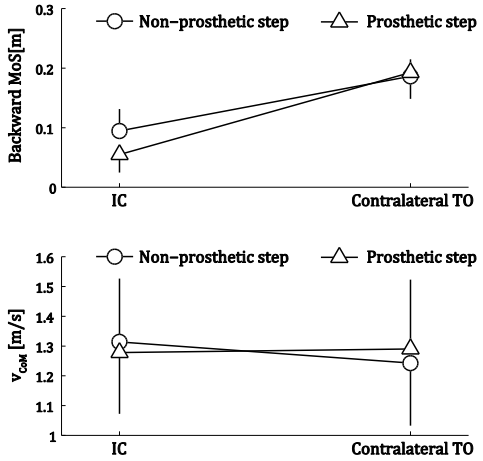

Figure 3: The average and between subjects standard deviation (n=10) of the backward margin of stability (MoS; upper panel) and the velocity of the center of mass (vCoM; lower panel) at initial contact (IC) and contralateral toe off (TO) of the prosthetic (O) and non-prosthetic (Δ) step.

Conclusion and discussion

In conclusion, step length asymmetry with a smaller FFP of the non-prosthetic step compared to the prosthetic step can be observed in people after transtibial amputation. This asymmetry caused a larger BW MoS for the non-prosthetic step at in initial contact and therefore preserved the BW MoS at the end of double support after the non-prosthetic step, in spite of a reduction of vCoM during this double support phase. Consequently, step length asymmetry in prosthetic gait could potentially be regarded as a functional adjustment to preserve sufficient BW MoS and prevent a backward fall in the presence of limited push-off ability of the prosthetic leg. The results of this study illustrate that the asymmetry in gait pattern for people after transtibial amputation is not necessarily a detrimental effect of the impairment, but could be beneficial in the regulation of gait stability. This should be considered in gait training for people after transtibial amputation.

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Gait adaptability evaluation in persons with a lower-limb amputation

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Abstract Persons with a lower-limb amputation have impaired balance control and a high prevalence of falls due to partial absence of muscular control of their prosthesis. Hence during walking, persons with a lower-limb amputation might experience difficulties with obstacle avoidance and visually guided stepping, especially when step adjustments need to be performed under time pressure. The C-Mill is an instrumented rehabilitation treadmill with visual context projected on the belt's surface that was developed specifically for training and evaluation of gait and gait adaptability. The aim of this study was to validate C-Mill gait adaptability evaluation protocols (i.e., the so-called WE-MOVE tracks) for persons with a lower-limb amputation by examining test-retest reliability and construct validity. Twenty-one persons with a lower-limb amputation participated in this study. Participants were tested twice within one week (test-retest). At each test, the WE-MOVE track was performed, a walking trail with obstacles and stepping targets that could unpredictably shift under time pressure during walking. In addition, Timed Up-and-Go (TUG) and 10 meter walking tests (10MWT) were performed (construct validity). WE-MOVE scores agreed well between test and retest. In contrast, no significant correlation was observed between WE-MOVE scores and TUG and 10MWT. WE-MOVE scores were reproducible from test to retest. The absence of significant correlations between WE-MOVE and standard clinical walking assessments suggest that the gait adaptability construct captured with WE-MOVE is not captured with the TUG and the 10MWT. Hence, WE-MOVE assessments likely add value to clinical diagnosis.

Keywords persons with a lower-limb amputation; gait adaptability; evaluation; C-Mill; WE-MOVE; test-retest reliability

Introduction

Although the majority of persons with a lower-limb amputation regain the ability to walk, they have a higher prevalence of falls, increased fear of falling, and reduced balance confidence during walking compared to healthy older adults (Miller et al., 2001). In addition, persons with a lower-limb amputation show a delayed response for step adjustments, which hampers their ability to timely adjust gait to visually perceived irregularities on the walking surface, as required for obstacle avoidance and visually guided stepping (Hofstad et al., 2009). Hence during walking, they might experience difficulties with adjusting their gait, especially under time pressure (Houdijk et al., 2012). Evaluating gait adaptability is likely to have an added value to the standard clinimetric tests, since it provides insight in the safety and quality aspects of walking. A possible instrument to evaluate gait adaptability is the C-Mill, which is an instrumented treadmill with visual context projected on the belt's surface to elicit step adjustments. The aim of this study was to validate C-Mill gait adaptability evaluation protocols (i.e., the so-called WE-MOVE tracks) for

persons with a lower-limb amputation by examining test-retest reliability. To further validate WE-MOVE tracks, the construct validity was analyzed by comparing WE-MOVE scores to scores obtained with Timed Up-and-Go (TUG) and 10 meter walking tests (10MWT).

Methods

Participants

For this study, twenty-one participants (age 53.4 ± 12.8 years) were selected from Reade, centre for rehabilitation and rheumatology (Amsterdam, the Netherlands), rehabilitation centre Heliomare (Wijk aan Zee, the Netherlands), and INAIL Centro Protesi (Budrio, Italy). To be included, participants must have a unilateral transtibial or transfemoral lower-limb amputation and able to walk 4 minutes with their prosthesis.

Protocol

Participants performed a gait adaptability protocol (WE-MOVE track, walking trails with obstacles and stepping targets) on the C-Mill twice within one week. Gait adjustments were required for accurate foot placement relative to the projected visual context. To facilitate evaluation of gait adjustments under time pressure, obstacles and stepping targets could unpredictably shift under time pressure during walking or suddenly change from a target to an obstacle (and vice versa). Determination of gait adjustments to this context allowed for assessment of gait adaptability. Participants performed WE-MOVE while walking at their comfortable walking speed in order to resemble real-life situations. In addition, participants performed the Timed Up-and-Go (TUG) and 10 meter walking tests (10MWT).

Variables

The software of the C-Mill provided a WE-MOVE score, a weighted average of obstacle-avoidance and target-hit success rates (in percentage). To successfully avoid an obstacle, both feet had to be placed outside the obstacle. To successfully hit a target, at least half of the foot had to be placed within the target.

Statistics

The test-retest reliability of WE-MOVE was analyzed by calculating the Intraclass Correlation Coefficient (ICC, absolute agreement) between WE-MOVE scores of test and retest. Additionally, a Bland-Altman plot was analyzed and the Coefficient of Repeatability (RC) was quantified, representing the value below which the absolute difference between two repeated measurements may be expected to lie with a probability of 95%. The construct validity was evaluated using Pearson's correlation between the clinimetric tests scores (TUG and 10MWT) and the WE-MOVE scores.

Results

WE-MOVE scores agreed well between test and retest, as evidenced by an ICC value of 0.76. There was only a small and insignificant bias (3%), but as depicted in the Bland-Altman plot (Figure 1) the limits of agreement (LoA) were rather wide, as further testified by a repeatability

coefficient of 23%. With regard to construct validity, we did not observe significant correlations between WE-MOVE scores and TUG and 10MWT.

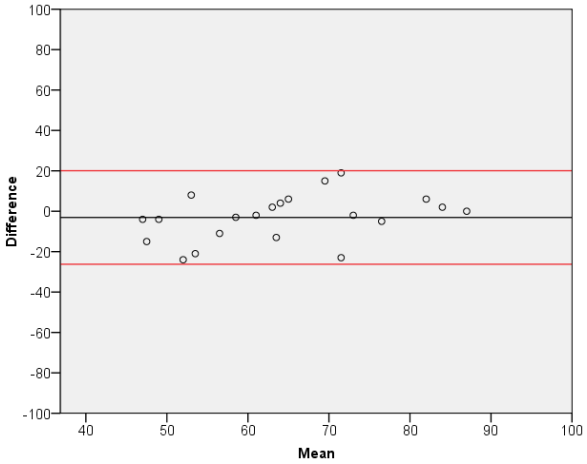

Figure 1. Bland-Altman plot of WE-MOVE scores (in %) between test and retest.

Conclusion and discussion

In conclusion, it can be stated that gait adaptability determined with WE-MOVE is test-retest reliable, however with a rather large repeatability coefficient. The absence of significant correlations between WE-MOVE and standard clinical walking assessments suggests that WE-MOVE assessments likely add value to clinical diagnosis because they capture a different construct. Therefore, these assessments may be considered as an integral part of walking ability evaluation, especially since gait adaptability is an important determinant of the risk of falls (Weerdesteyn et al., 2006).

Acknowledgements

This work was supported by ISPO Nederland. ForceLink is acknowledged for their technical support regarding the software for the development of WE-MOVE.

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Oral presentations
Wednesday, April 23, 2014

Keynote lecture 3: Prof. Dr. Ir. J. Harlaar

Future rehabilitation diagnostic technology: matching therapies to patients

Harlaar J

In rehabilitation medicine restoring or preserving mobility is a main treatment goal for many patients. Mobility - more specific: being able to walk - is a highly valued activity because it vastly contributes to self-fulfillment in the context of living a meaningful life. There are many treatments in the context of rehabilitation medicine to promote walking performance. More general treatments are based on exercises and target the overall adaptive mechanisms of the human body. Direct interventions address the restoration of functions, or minimizing impairments of joint or muscle functions. Complete restoration of normal function is usually impossible, but functional gain (as the optimal result) is certainly achievable in many cases.

However currently there is either a lack of evidence of common interventions in rehabilitation medicine to promote mobility, or studies show confliction results. Generally , these studies suggest that the heterogeneous nature of the population prevents to conclude a simple effect of a specific therapy. As a consequence the challenge of research in rehabilitation to promote mobility is to distinguish responders from non-responders. Clinical gait analysis is a technology that reveal the biomechanics of joint and muscle function during gait. Gait analysis based assessment could answer hypotheses regarding determinants of successful treatment modalities. These parameters from gait analysis cover the characteristics of the structures that are addressed by the specific therapeutic intervention.

Basically there are two pathways to arrive at accurate determinants of successful therapies. First adequate biophysical model representations of the human musculoskeletal system, will enable to apply causal reasoning towards the intervention. Decisions on the complexity of such models require to have insight in the mechanics of normal walking and the aetiology of pathological walking. With such approach an illustration that suggest a treatment algorithm to prescribe ankle foot orthosis will be given. Secondly, probabilistic modeling might be able to reveal successful treatment algorithms , without the need to explicit a (supposed) working mechanism. This requires (retrospective) analysis of large clinical datasets, with a high level of quality. Assuming that clinical practice is not without errors, this approach enables to prevent making the same mistakes again. A European initiative (MD-PAEDIGREE) aims at implementing both approaches to improve treatments of mobility in children with cerebral palsy.

Oral presentations
Thursday, April 24, 2014

Keynote lecture 4: Prof. Dr. C.E. Garber

Physical activity guidelines for people with a disability

Garber CE

Regular engagement in physical activity and reducing sedentary time is essential for good health of all children and adults. Current physical activity guidelines apply to children and adults with functional limitations or disability, who are more likely than able-bodied persons to meet these guidelines. The current physical activity recommendations for aerobic, muscle strengthening, flexibility and neuromotor exercise for all adults and children will be described. Interrupting sedentary time with short activity bouts is advocated. A variety of exercises can be incorporated into an physical activity program and the goals of the program may change over time. For adults and children, an individualized physical activity program that takes into consideration individual preferences, physical and mental health limitations, and physical fitness is important. Progression of the physical activity program is in accordance with individual responses, which may be quite variable. In persons with disabling conditions, a prolonged period of time may be necessary to achievement of the recommended targets for physical activity. However, it should be emphasized that there are many health benefits in physical activity, even if the recommended targets for physical activity are not met. Attention to behavioral supports and health behavior change strategies, will facilitate adoption and maintenance of a regular physical activity program. Enjoyment is an important element in any physical activity program and incorporation of variety, play, socialization, and music can enhance the pleasantness of the physical activity experiences. The challenges to people with functional limitations or disability in meeting physical activity recommendations can be considerable, and suggestions for addressing these challenges will be presented.

Oral presentations
Thursday, April 24, 2014

Session 5: Exercise & Testing

Submaximal exercise parameters during arm ergometry exercise testing in patients with spinal cord injuries

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Abstract *Purpose:* Submaximal exercise parameters, such as minute ventilation to carbon dioxide elimination slope (VE/VCO2 slope), oxygen uptake efficiency slope (OUES), and oxygen uptake efficiency plateau (OUEP), have been reported to be associated with cardiorespiratory fitness and the risk of hospitalization in patients with heart failure. The purpose of this study was to investigate the submaximal exercise parameters during arm ergometry exercise testing in patients with spinal cord injuries and able-bodied participant. *Methods*: A total of 31 male patients with chronic spinal cord injuries (24 paraplegia, 7 tetraplegia), and 24 able-bodied male participants were recruited in the study. All subjects were examined by an arm ergometry exercise testing. The able-bodied participants also received a leg ergometry exercise testing. We evaluated submaximal exercise parameters of each exercise test, including VE/VCO2 slope, OUES, and OUEP. *Results:* The main findings included: 1) Comparing with leg ergometry, significantly higher VE/VCO2 slope and significantly lower OUES and OUEP were observed during arm ergometry among the able-bodied participants ($p < 0.05$); 2) Patients with tetraplegia showed significantly lower OUES as compared with the able-bodied participants ($p < 0.05$), but no difference was found between patients with paraplegia and able-bodied participants; 3) There is no significant difference in VE/VCO2 slope and OUEP among the study subjects during arm ergometry; (4) OUES is significantly positively correlated with peak oxygen uptake in patients with spinal cord injuries and able-bodied participants in both arm and leg ergometry ($p < 0.05$). *Conclusions:* Submaximal exercise parameters were significantly different between arm and leg ergometry exercise testing. OUES, positively correlated with cardiorespiratory fitness, is significantly different among patients with tetraplegia, paraplegia and able-bodied participants.

Keywords submaximal exercise parameters, arm ergometry, spinal cord injury, VE/VCO2 slope, OUES,OUEP

Introduction

Cardiopulmonary exercise testing(CPET) is widely used in clinical practice to assess the response of both patients and healthy people to exercise. Some parameters have been reported to be associated with cardiorespiratory fitness and prognosis of patient with heart failure[1,2]. Among them, peak oxygen consumption (VO_{2peak}) and HR reserve (HRR), are both maximal exercise parameters. Due to patients' exercise intolerance, several submaximal exercise parameters have also been introduced to evaluate the cardiopulmonary functional reserve, including minute ventilation to carbon dioxide elimination slope (V_E/VCO_2 slope), oxygen uptake efficiency slope (OUES)[3], and oxygen uptake efficiency plateau (OUEP)[4]. Previous study

suggested that arm ergometry exercise testing could be used for persons unable to cycle[5]. However, such data in patients with spinal cord injury are still limited. We investigated the submaximal exercise parameters during arm ergometry exercise testing in patients with spinal cord injuries and able-bodied participants. We also compared arm and leg ergometry exercise testing results in able-bodied participants.

Methods

Participants

A total of 31 male patients with chronic spinal cord injuries (24 paraplegia, 7 tetraplegia), and 24 able-bodied male participants were examined by an arm ergometry exercise testing. The able-bodied participants also received a leg ergometry exercise testing. Relevant clinical data were collected from medical records and clinical interviews. All study participants and their parents provided written informed consents, and the institutional review committee of the National Taiwan University Hospital approved the study protocol

Cardiopulmonary exercise testing

Both the arm(Hand crank ergometer ER800SH, Erich Jaeger GmbH, Germany) and leg ergometry used the modified Bruce protocol. The 12-lead electrocardiogram and heart rate were recorded continuously during the test and continued for five minutes of the recovery period. Blood pressure was measured every 2 minutes. The hemodynamic changes such as cardiac output、stroke volume、heart rate、total peripheral resistance were monitored using non-invasive methods (Cheetah Reliant, Cheetah Medical, Inc.,Oregon, USA). Minute ventilation (V_E in l/min), oxygen uptake (VO_2 in l/min) and carbon dioxide production (VCO_2 in l/min) were acquired breath-by-breath, using a gas analyzer (MetaMax 3B, Cortex Biophysik GmbH, Germany). Gas analysis was preceded by calibration of the equipment and began two minutes prior to exercise. Participants were encouraged to perform exercise until theVc_{O2}/V_{O2} ratio (respiratory exchange ratio, RER) was ≥1.10. All studies were stopped by subjective fatigue or dyspnea preventing the participants from continuing the exercise. VO_{2peak} was expressed as the highest VO2 attained during exercise. The V_E/VCO_2 slope was calculated as the slope of the regression line relating V_E to VCO_2 during exercise, with data obtained over the complete duration of exercise. OUES was calculated by averaging V_E and VCO_2 over 10-second intervals, for the entire exercise duration, using the following equation: VO_2 (l/min) = a (log10 V_E) + b, where a = OUES. OUEP was calculated as VO_{2peak} /log10 peak V_E.

Statistic analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS,Version 15.0; SPSS Inc., Chicago, IL) and R statistical software,Version 2.11.1 (R Foundation for Statistical Computing,Vienna, Austria). A P value of 0.05 was considered statistically significant.

Results

Our results showed that patients with tetraplegia showed significantly lower OUES as compared with the able-bodied participants ($p < 0.05$), but no difference was found between patients with paraplegia and able-bodied participants. There is no significant difference in V_E/VCO_2 slope and OUEP among the study subjects during arm ergometry. OUES was significantly positively correlated with peak oxygen uptake in patients with spinal cord injuries and able-bodied

participants in both arm and leg ergometry ($p < 0.05$). Besides, comparing with leg ergometry, significantly higher V_E/VCO_2 slope and significantly lower OUES and OUEP were observed during arm ergometry among the able-bodied participants ($p < 0.05$).

Conclusion and discussion

Submaximal exercise parameters were significantly different between arm and leg ergometry exercise testing. OUES, positively correlated with cardiorespiratory fitness, is significantly different among patients with tetraplegia, paraplegia and able-bodied participants.

Acknowledgements

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Accelerated peripheral compared to central perceived exertion during maximal arm exercise tests in spinal cord injury

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Abstract The purpose of this study was to describe the rise of both central (CRPE) and peripheral (PRPE) ratings of perceived exertion (RPE) during maximal arm exercise tests in individuals with spinal cord injuries (SCI). 39 individuals with SCI were recruited for this study and were divided into groups based on injury level: tetraplegia (n=23; AIS A-D; age 40.7±10.9 years; TPI 12.6±9.7 years) and paraplegia (n=16; AIS A-C; age 42.4±11.2 years; TPI 13.0±11.0 years). All individuals completed incremental exercise tests with power output (PO) increasing every minute (5W/min for tetraplegia; 10W/min for paraplegia). CRPE and PRPE on the Borg CR10 scale were collected every minute until volitional exhaustion. RPE data was plotted as a percentage of maximum PO and regression analysis was performed to fit the datasets to either a linear, quadratic or cubic function. In tetraplegics, both CRPE and PRPE were best fit by quadratic functions. In paraplegics, both CRPE and PRPE were best fit by cubic functions. PRPE regressions had a higher slope than CRPE regressions for both individuals with tetraplegia ($p<0.01$) and paraplegia ($p<0.01$). While lesion level did not impact CRPE regressions ($p=0.34$), the slope of the PRPE regression was higher in tetraplegics versus paraplegics ($p<0.01$). During maximal arm ramp exercise in SCI, the rise in peripheral RPE is faster than central RPE. Further, in tetraplegics, PRPE appears to have an accelerated increase when compared to paraplegics. Since maximal arm exercise appears to be peripherally limited in all subjects, perhaps standard ramp protocols should be revisited in attempt to limit the rise in peripheral exertion to better assess central responses.

Keywords Spinal Cord Injury, Ratings of Perceived Exertion, Progressive Exercise

Introduction

Maximal exercise tests in individuals with spinal cord injury (SCI) rely on upper-limb muscles to measure maximal aerobic capacity. While ratings of perceived exertion (RPE) are well correlated with higher intensity cardiorespiratory responses in able-bodied individuals, the validity of this relationship in SCI has been questioned (Lewis, Nash et al. 2007). Differentiating RPE measures into central and peripheral components may help describe the relationship between perceived exertion and exercise responses; specifically, how fatigue develops during progressive exercise. Peripheral factors, in particular, may dominate the perceived effort at higher exercise intensities, which may be more evident in individuals with tetraplegia given their greater upper-limb functional and mobility impairments. The purpose of this study was to describe the rise in both central (CRPE) and peripheral (PRPE) RPE during maximal arm exercise tests in individuals with either tetraplegia or paraplegia.

Methods

Participants

39 individuals with SCI were recruited for this study and were divided into groups based on injury level: tetraplegia (n=23; AIS A-D; age 40.7±10.9 years; TPI 12.6±9.7 years) and paraplegia (n=16; AIS A-C; age 42.4±11.2 years; TPI 13.0±11.0 years). All participants were free from known cardiovascular disease and were able to complete the exercise protocol without adverse events.

Exercise Protocol

Maximal exercise tests were performed on an electronically braked Lode arm ergometer (Angio V2, Lode BV, Groningen, NED). After a one minute warm-up at 0W, power output (PO) was increased every minute (5W/min for tetraplegia; 10W/min for paraplegia), or as required to reach an exercise test duration of 8-12 minutes. CRPE and PRPE on the Borg category-ratio 10-point scale (CR10) were collected every minute until volitional exhaustion (i.e., cycling rate < 40 rpm). Participants were specifically instructed to report the how hard they were working with their 'heart and lungs' for CRPE and 'arms and shoulders' for PRPE.

Data Analysis and Statistics

RPE data was plotted as a percentage of maximum PO and regression analyses were performed to fit the datasets to either a linear, quadratic or cubic function. One-way ANOVAs were performed to determine which function best fit the individual datasets (i.e., RPE and CRPE for both individuals with tetraplegia and paraplegia). One-way ANOVAs were also used to assess if multiple curves were distinctly unique, or if they could be adequately represented by one model. In cases where curves were not unique based on statistical analysis, the simplest mathematical model was assumed to provide the "best fit". Analyses were performed on GraphPad Prism 5 (Version 5.0a, GraphPad Software, San Diego, CA, USA) and significance was set at $p<0.05$.

Results

In individuals with tetraplegia, both CRPE and PRPE were best fit by quadratic functions (Figure 1; CRPE: quadratic vs cubic, $p=0.15$, $R^2=83\%$; PRPE: quadratic vs cubic, $p=0.27$, $R^2=92\%$). In individuals with paraplegia, both CRPE and PRPE were best fit by cubic functions (Figure 1; CRPE: quadratic vs cubic, $p=0.02$, $R^2=89\%$; PRPE: quadratic vs cubic, $p=0.02$, $R^2=91\%$). PRPE regressions had a higher slope than CRPE regressions for both individuals with tetraplegia ($p<0.01$) and paraplegia ($p<0.01$). While lesion level did not impact CRPE regressions ($p=0.34$), the slope of the PRPE regression was higher in tetraplegics versus paraplegics ($p<0.01$).

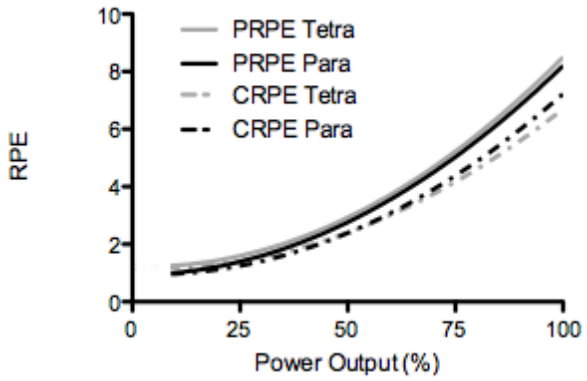

Figure 1. Development of central (dashed) and peripheral (solid) fatigue in individuals with tetraplegia (grey; quadratic) and paraplegia (black; cubic).

Conclusion and discussion

During maximal arm ramp exercise in SCI, the rise in peripheral RPE is faster than central RPE. Further, in individuals with tetraplegia, PRPE has an accelerated increase when compared to individuals with paraplegia, likely due to group differences in peripheral responses to progressive exercise (i.e., upper-limb motor score, autonomic impairment, lactate accumulation, fatigue due to greater percentage of Type II muscle fibres). In able-bodied individuals, peripherally and centrally active metabolic compounds seem to best predict the global RPE response at both moderate and vigorous intensities (Pires, Lima-Silva et al. 2011). Autonomic dysfunction (i.e., afferent signaling, temperature regulation) is an understudied component of the exercise response, and may play an important role in describing the fatigue response in tetraplegia. Future studies should assess autonomic function during maximal arm exercise in individuals with SCI. Since maximal arm exercise appears to be peripherally limited in all SCI participants regardless of classification, perhaps standard ramp protocols should be revisited in attempt to limit the rise in peripheral exertion and facilitate assessment of central limitations during tests of aerobic fitness.

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Arm ergometry versus wheelchair propulsion for testing aerobic fitness in wheelchair-using children

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Abstract *Purpose:* Knowledge regarding physiologic response during maximal exercise testing in wheelchair dependent youth is limited. Arm cranking protocols are most frequently used. A recent review, however, regarding wheelchair testing suggests that these protocols lack specificity to wheelchair propulsion and therefore question their validity.To compare peak oxygen uptake (VO_{2peak}) and heart rate (HR_{peak}) using a Graded Arm Ergometry Test (GAET) and a Graded Wheelchair Propulsion Test (GWPT) in wheelchair dependent children. *Methods: C*hildren with Spina Bifida participated in this validity and reproducibility study. They perfomed both GAET and GWPT and test retest for GWPT. Physiologic responses were measured during GAET (Lode Angio) and GWPT (Cateye wheelchair roller band) using a heart rate (HR) monitor and calibrated mobile gas analysis system (Cortex Metamax). For validity, VO_{2peak} and HR_{peak} were compared between GAET and GWPT using paired t-tests and Pearson correlation coefficients. For preliminary reproducibility, the intra-class correlation (ICC) and paired t-tests were calculated for both VO_{2peak} and $HR_{peak.}$ *Results:* The study population consisted of 13 children (mean age 13.4 years). Both VO_{2peak} and HR_{peak} were higher during the GWPT in comparison to GAET (23.9 vs. 19.5 ml/kg/min $p=0.07$; 171 vs. 156 bpm $p<0.05$). Preliminary results for reproducibility of GWPT show only small and non-significant differences and high significant correlations between test and re-test for both VO_{2peak} (difference=1.08 ml/kg/min and ICC=.92) and HR_{peak} (difference=4.1 beats and ICC=.88). *Conclusion:* This pilot study shows higher VO_{2peak} and HR_{peak} during GWPT. At the same time, preliminary reproducibility data suggests excellent reproducibility of GWPT. We recommend to perform a wheelchair propulsion test in the assessment of aerobic fitness testing in this population instead of using classic arm cranking protocols.

Aerobic training on hemodynamics during head-up tilt and exercise testing in patients with spinal cord injuries

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Abstract The purpose of this study was to investigate the hemodynamics during head-up tilt (HUT) and cardiopulmonary exercise testing (CPET), and the effect of aerobic training in patients with spinal cord injuries (SCI). 7 tetraplegic, 5 paraplegic patients, and 24 healthy controls were recruited. All subjects received HUT and CPET using arm ergometry. Hemodynamic parameters were continuously monitored during HUT and CPET, using a noninvasive bioreactance-based system. 5 SCI patients completed 36 sessions (30 minutes/session, 2-3 times/week) of arm ergometry training over a period of 3- 6 months. The results showed significant differences in the hemodynamics during HUT and CPET among patients with tetraplegia, paraplegia, and healthy subjects. Aerobic training might improve peak exercise performance and peak cardiac output (CO) during CPET, but it did not have a significant effect on the hemodynamics during HUT.

Keywords spinal cord injury, head-up tilt, arm ergometry, tetrapelgia, paraplegia, NICOM

Introduction

Cardiovascular complications are major causes of mortality in the SCI population (West, Alyahya et al. 2013). Orthostatic hypotension is a common problem SCI patients may encounter during rehabilitation and activities of daily living (Huang, May-Kuen Wong et al. 2013). Exercise training can improve cardiovascular fitness by increasing physical work capacity and VO2max in patients with SCI (Phillips, Cote et al. 2011). Few studies measured CO and total peripheral resistance (TPR) using noninvasive CO measurement (NICOM) system during CPET. The purpose of this study was to understand the hemodynamics during HUT and CPET using the NICOM, and the effect of aerobic training in SCI patients, hopefully to assist with future rehabilitation prescription.

Methods

Participants

Participants were recruited from National Taiwan University Hospital (NTUH), including 7 males with C4–T1 tetraplegia (mean age 38.4±7.7 yr), 5 males with T6–L2 paraplegia (mean age 40.0±7.5 yr) and 24 healthy males (mean age 44.7±5.5 yr). Subjects with history of heart disease or pacemaker use were excluded. All subjects signed informed consent before participation.

NICOM

The noninvasive bioreactance-based system was used for continuous monitoring of hemodynamic changes during HUT and CPET.

The head-up tilt (HUT)

Subjects were placed on a tilt table. Hemodynamic parameter recording was started after 5 minutes of supine resting period. The initial supine phase lasted for another 5 minutes, participants were then tilted up to 60 degrees for 10 minutes (HUT phase) before returning to the supine phase for the final 5 minutes (tilt-reversal phase).

The CPET by arm ergometry

The test began with a resistance of 0 W for two minutes as warm-up. Resistance was then increased by 10 W every minute with the cycling rate set at 50±10 RPM. The cycling continued until participants' volitional exhaustion. The resistance then gradually decreased to 0W and entered a 3-minutes cool-down phase.

Exercise training with arm ergometry

All 12 SCI patients were invited to join the arm ergometry exercise training. 5 SCI patients have completed 36 sessions (30 minutes /session, 2-3 times/week, over 3-6 months) of training, which was instructed by an experienced cardiopulmonary physiotherapist. Except for a 30-minute continuous training in the last 6 sessions (week 11-12), an interval training protocol consisting of repeated bouts of 1- to 15-minute exercise (1, 2, 3, 6, 12, 15 min. for week 1, 2, 3-4, 5-6, 7-8, 9-10, respectively) with one-minute rest in between during a 30-minute session was employed. The exercise intensity was set at 50-80% of the peak VO2.

Statistical analysis

Between group comparisons for baseline continuous variables were made using the Kruskal-Wallis Test. Post hoc analyses was used to examine the specific differences between two groups. Mixed-model analysis was used to evaluate between-group and between-phase difference and also the interaction between group and phase during HUT. Comparison before and after arm ergometry aerobic training was done using the Wilcoxon signed-rank test. A P value < 0.05 was considered statistically significant.

Results

Participants

There were no significant differences between groups in participant characteristics, including age, body weight, height, body mass index (BMI) and waist circumference.

The HUT

Significant differences in heart rate (HR), blood pressure (BP), CO, stroke volume (SV), and TPR were observed between supine, head-up tilt, and tilt reversal phases. Significant difference existed among the tetraplegic, paraplegic, and able-bodied control groups in BP ($p<0.05$) and total peripheral resistance index (TPRI) ($p=0.0260$). There was significant interaction between study group and HUT in BP ($p<0.0001$) and TPR ($p=0.0218$).

CPET

Resting BP and peak work rate were significantly lower in the tetraplegics compared to healthy control ($p<0.05$) and paraplegia group ($p<0.05$). Peak BP, peak HR, peak oxygen uptake, and peak oxygen pulse were significantly lower in tetraplegics than in healthy control ($p<0.05$). No significant differences were found in all the above measurements between the paraplegics and the healthy controls.

Exercise training with arm ergometry

Peak work rate significantly increased after training ($p=0.0184$). Peak CO also increased ($p=0.0514$). No significant change was observed during the HUT tests before and after training

Conclusion and discussion

Tetraplegic patients exhibited more prominent cardiovascular impairment compared to the paraplegic and control groups, both during exercise and orthostatic challenge with HUT. The increase in peak work rate, peak CO, SV and minute ventilation after arm ergometry training indicate that cardiopulmonary fitness and physical performance can be improved through exercise training in SCI patients.

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Oral presentations
Thursday, April 24, 2014

Session 6: Physical Activity 1

Narratives of activity-based rehabilitation for people with spinal cord injury

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Abstract Active Rehabilitation is an activity-based rehabilitation programme that uses physical activity for people with spinal cord injury (SCI) to improve health and well-being. Currently little is known about the impact of this activity-based rehabilitation programme on their clients. The purpose of this study was to explore the experiences of clients at Active Rehabilitation, their expectations of the programme, the influence of social relations and the consequences on health and well-being. Participant observations were carried out at the rehabilitation centre for one year. Semi-structured interviews were completed with eight clients with SCI and all five trainers delivering the programme. Interview and observational data were subjected to a narrative analysis. All clients drew upon elements of the "restitution narrative" – characterised by a commitment to a recovery. Three clients' stories were firmly aligned with restitution and the desire to walk again. The other five clients, through a process of narrative reconstruction, told stories borrowed from restitution. This new story hoped for functional restoration and improved physical fitness, without the promise of walking again. Clients' stories were relational in that they were co-constructed by family members and rehabilitation trainers both prior to and during the rehabilitation programme. There are a number of implications for rehabilitation and research that are critically discussed. Firstly, restitution as a motivating strategy can have dangerous consequences on health and well-being. Secondly, a new emerging story that is partially borrowed from restitution could be beneficial in promoting physical activity and managing expectations. Lastly, all stories are relational and therefore the influence of both family and trainers must be considered when in a rehabilitation setting.

Keywords spinal cord injury, narrative, rehabilitation, physical activity

Introduction

Being physically active has the potential to improve health, well-being and the quality of life for people with spinal cord injury (Martin Ginis et al., 2012). Despite these benefits, people with SCI are within the most inactive segment of society that comprises disabled people (Letts et al., 2011). In an effort to help reverse inactivity after paralysis, the first UK Activity Rehabilitation centre developed an activity-based rehabilitation programme for people with spinal cord injury (SCI).

Activity-based rehabilitation combines neurological rehabilitation with exercise physiology to produce individual exercise programmes. These activity-based rehabilitation programmes are designed to maximize a client's physiological and neurological potential to improve health and well-being. Thus, this rehabilitation context is not only concerned with the physiological aspects of SCI but also the psycho-social dimensions. Perrier et al (2013) identified how different disability narratives motivated engagement in activity-based rehabilitation. Currently however, little is

known about the impact of this activity-based rehabilitation programme on clients over time. The purpose of this study was to explore the experiences of clients' at Active Rehabilitation, their expectations of the programme, the influence of social relations and the consequences on health and well-being over time.

Methods

Narrative inquiry was adopted for this study to focus on the storied experiences of the process of activity-based rehabilitation. Narrative inquiry seeks to explore how individual stories are shaped by both personal and social experiences (Sparkes and Smith, 2014).Therefore examining stories is one way to understand not only the personal experiences of clients' at Active Rehabilitation, but also how these experiences are shaped by others both within and outside of the centre.

Both semi-structured interviews and participant observation were used to explore the experiences of clients and staff at Active Rehabilitation. Life history interviews were used with the eight clients to explore life with SCI, the role of PA and the experiences of activity-based rehabilitation. The use of interviews also enabled the five rehabilitation staff to share their experiences of developing activity-based rehabilitation with people with SCI. To complement the storied experiences constructed through interviews, participant observation was carried out at the rehabilitation centre for one year.

Results

All clients drew upon elements of the restitution narrative which is a common storyline that projects hope for recovery or cure after illness or injury (Frank, 2013). Three clients' stories were firmly aligned with restitution and the hope to walk again. Participants who constructed their stories using restitution were using activity-based rehabilitation in the hope to recover from their SCI:

Interviewer: "Why do you come to Active Rehabilitation?"

Client 1: "Get back to how I was, get walking."

The other five clients, through a process of narrative reconstruction, told stories borrowed from, but different to, classic restitution. This new story drew upon hope for functional restoration and improved physical fitness, without the promise of walking again:

Interviewer: "Do you have any goals you are trying to achieve at Active Rehabilitation?"

Client 2: "Staying as fit as I can. Getting back on my feet and walking like I was is not going to happen."

Clients' desire for restitution does not however spring from their individual minds or can be traced to the individual. Rather, when read through narrative theory, restitution stories are constituted relationally. For example, stories were relational in that they were co-constructed with and by family members along with rehabilitation trainers both prior to and during the rehabilitation programme. Stories were framed by family members prior to entering the centre as they were often the people to first make contact with the Active Rehabilitation. Many clients also relied on the support, in terms of finances, transport and motivation, from family and friends to be able to attend the centre. The trainers were central to clients' experiences of activity-based rehabilitation but they reported difficulty in managing clients' expectations of the programme and negotiating realistic goals:

Interviewer: "Do you have to manage expectations of this programme?"

Trainer 1: "Some clients obviously want to walk again. I'm kind of negative with it when I talk to them. I guess I'm more of a realist but I don't like to pump up expectations whatsoever."

Conclusion and discussion

A number of implications for rehabilitation and research emerge from this study. Firstly, the possible adverse consequences of restitution as a motivating strategy for activity-based rehabilitation need to be addressed. A preoccupation with recovery can be problematic and negatively impact health and well-being. This is because stories of hope for a specific medical outcome, such as walking after SCI, can facilitate engagement in rehabilitation but have dangerous consequences on health and well-being if recovery is not fulfilled (Williams et al., 2014).

Secondly, and a unique finding from this research, a new emerging story that is partially borrowed from restitution was identified. This new narrative that is in its infancy could be beneficial in promoting physical activity and managing expectations. This story provides an alternative narrative whereby participating in activity-based rehabilitation is aimed at improving health and well-being without the promise of walking again.

Lastly, and contra cognitive theory, all stories are relational and therefore the patterns of relations (e.g. family and trainers) must be considered when in a rehabilitation setting. Rather than starting out from individuals or tracing ideas from the mind, as cognitive theory does, practical applications need to emerge from relationships and the social meanings brought to contexts like rehabilitation. The stories that family members and trainers promote regarding activity-based rehabilitation will impact upon the expectation that clients have of the programme.

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Understanding and quantifying aerobic capacity during rehabilitation in lower limb amputees

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Abstract Previous research has shown that the aerobic capacity of subjects who were comfortably walking with a lower limb prosthesis is markedly reduced compared to healthy controls. Moreover, aerobic capacity proves to be an important determinant for walking. In this study, information is gathered about the peak aerobic capacity of subjects at both the start and end of prosthetic rehabilitation. Currently, all eligible patients admitted for prosthetic rehabilitation in two rehabilitation centre are undergoing peak aerobic capacity testing at the start and end of rehabilitation. Peak aerobic capacity is tested using a graded one-legged exercise test. So far, peak aerobic capacity is determined of 11 patients at the start of prosthetic rehabilitation. Of this group 2 were amputated as a result of cancer while the remaining 12 were amputated due to vascular deficiency. For this group peak aerobic capacity was on averaged 16.43 $mlkg^{-1}$ min^{-1} [range 7.4- 28.6] which was comparable to the post rehabilitation vascular amputee group (n=10, p= .799) and markedly lower than the post rehabilitation trauma (p< .001) and control group (p< .001). Fortunately, preliminary results show that in some cases, marked improvements in aerobic capacity can be attained at the end of rehabilitation, this was also the case in vascular amputee subjects presented with a substantial number of co-morbidities. Preliminary results strengthen the notion that the peak aerobic capacity at the start of rehabilitation is markedly reduced. As sufficient aerobic capacity may prove to be a prerequisite for comfortable prosthetic ambulation, aerobic training ought to be part of rehabilitation. Currently, data collection is ongoing, and measurements at discharge are obtained.

Keywords lower limb amputation, physical capacity, aerobic load, rehabilitation, prosthetic walking

Introduction

There is a plentitude of literature available that convincingly show that walking with a lower limb amputation is a strenuous activity (Waters, Perry et al. 1976). Currently a lot of extremely interesting developments are being undertaking to enhance and optimize the actual prosthesis. However, research and clinical practice has made it clear that providing a state-of-the-art

prosthesis does not guarantee that the person will regain and maintain their walking ability. This particularly is true for those people that have had to undergo amputation due to vascular deficiency. Recent research findings has confirmed clinical practice that prosthetic walking ability is to a large extent related to the aerobic capacity of the person walking with the prosthesis (Wezenberg, van der Woude et al. 2013). Interestingly, only sporadic research efforts have been made to quantify the aerobic capacity of the amputee population during prosthetic rehabilitation. With the development of an exercise test that can be reliably and safely used to determine the aerobic capacity in people who underwent lower limb amputation (Wezenberg, de Haan et al. 2012) we are able to quantify the aerobic capacity of people at the start of prosthetic rehabilitation. The aim of this study is to determine the aerobic capacity of subjects at the start of prosthetic rehabilitation and to compare these values with those obtained previously of subject who were already walking comfortably with their prosthesis.

Methods

All eligible patients admitted for prosthetic rehabilitation in two rehabilitation centre are undergoing peak aerobic capacity testing at the start and end of rehabilitation. Peak aerobic capacity (VO_{2peak}) is tested using a graded one-legged exercise test, which has been described elsewhere (Wezenberg, de Haan et al. 2012). Currently a total of 14 have been tested (age=57.7 years, sd=18.8; weight=82.4 kg, sd= 20.4). Of this group 2 were amputated as a result of cancer while the remaining 12 were amputated due to vascular deficiency. Values are compared with those obtained previously from a group of elderly subjects who had finished prosthetic rehabilitation. Comparison is made using a *t*-test. Statistical significance was set at p=.05.

Results

Averaged VO_{2peak} was 16.43 $mlkg^{-1}min^{-1}$ [range 7.4- 28.6] which was comparable to the post rehabilitation vascular amputee group (n=10, p= .799), and markedly lower than the post rehabilitation trauma (28.1 $mlkg^{-1}min^{-1}$, p< .001) and control group (30.8 $mlkg^{-1}min^{-1}$, p< .001). Of the 14 subject tested, six had undergone aerobic capacity testing at discharge. Of this group two showed marked improvements in the aerobic capacity while for the remaining four only very marginal or no change in peak aerobic capacity was found.

Conclusion and discussion

Preliminary results strengthen the notion that the peak aerobic capacity at the start of rehabilitation is markedly reduced compared to healthy subject without an amputation. While bearing in mind the limited number of subjects measured so far, it is interestingly to notice that the aerobic capacity of the vascular amputee subjects who just started prosthetic rehabilitation is not statistically different from that of vascular amputees who are already walking with their prosthesis. Because sufficient aerobic capacity may prove to be a prerequisite for comfortable prosthetic ambulation, current results entail that aerobic training ought to be a integrated part of prosthetic rehabilitation.

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What determines exercise self-efficacy in persons with recent spinal cord injury?

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Abstract Exercise self-efficacy (ESE) is the confidence persons have in their ability to exercise. The purpose of this study was to assess determinants of ESE in persons with recent SCI. Firstly, personal and lesion characteristics as determinants that could be used to identify subgroups with lower ESE; and secondly potentially modifiable determinants from a rehabilitation perspective: body mass index (BMI), fatigue, pain and aerobic capacity. Measurements were performed two months prior to discharge from inpatient rehabilitation. Thirty-seven wheelchair-bound persons with recent SCI participated and completed the Exercise Self-Efficacy Scale, the Fatigue Severity Scale, and Chronic Pain Grade. Furthermore, age and lesion characteristics were recorded, BMI determined, and aerobic capacity measured during a maximal hand-cycling test. Separate regression models show that age and lesion characteristics were not significantly related to ESE. Of the potentially modifiable determinants, only BMI ($B = -0.28$, $p = 0.03$) and fatigue ($B = -1.64$, $p < 0.01$) were significantly related to ESE. It can be concluded that age and lesion characteristics were no determinants of ESE and therefore can not be used to identify subgroups of persons with lower ESE. Furthermore, higher BMI and more fatigue were related to lower ESE, which seems to underscore the importance of weight and fatigue management during inpatient rehabilitation.

Keywords Spinal cord injury, exercise, physical behavior, rehabilitation

Introduction

Exercise self-efficacy (ESE), the confidence persons have in their ability to exercise, is an important and modifiable predictor of exercise and physical activity behavior. Persons with higher ESE are more likely to be successful at exercise adherence. By helping persons with SCI to increase ESE, practitioners may be more successful in achieving higher levels of exercise and physical activity (Ashford, Edmunds et al. 2010). Factors influencing ESE in persons with recent SCI are unknown.

The goal of the current study was to assess ESE and its determinants in persons with SCI during inpatient rehabilitation. Firstly, we assessed age and lesion characteristics as determinants of ESE. Next, we assessed potentially modifiable determinants from a rehabilitation perspective: body mass index (BMI), aerobic capacity, fatigue and pain. Knowledge of ESE and its

determinants may assist in identifying subgroups of persons with lower ESE who could benefit from more attention. Furthermore, this study is important to further develop and optimize interventions targeting ESE.

Methods

This study is part of a longitudinal multi-center randomized controlled trial, Act-Active, that evaluates the added value of a behaviorally focused intervention on physical behavior, physical fitness and health among persons with recent SCI. In the current study, baseline data of the longitudinal study that were collected previous to the start of the interventions of Act-Active, two months before discharge from inpatient rehabilitation, were analysed.

Participants

Persons aged 18 to 65 years with recent SCI were recruited from four Dutch rehabilitation centers: Rijndam in Rotterdam, Adelante in Hoensbroek, Heliomare in Wijk aan Zee and De Hoogstraat in Utrecht. To meet inclusion criteria, persons had to be involved in initial inpatient rehabilitation following SCI and use a manual wheelchair.

Measurements

ESE was assessed using the Dutch Exercise Self-Efficacy Scale (ESES) (Nooijen, Post et al. 2013). The ESES consists of 10 items about self-confidence level with respect to performing exercise and daily physical activities. We recorded age and lesion characteristics, calculated BMI, and during a maximal hand-cycling test we determined aerobic capacity; peak oxygen uptake and peak power output. Participants completed the Fatigue Severity Scale, and Chronic Pain Grade. Separate regression models were used to assess determinants, correcting for confounding variables when necessary.

Results

Thirty-seven wheelchair-bound persons with recent SCI participated; mean age 43 (SD=14) years, 86% men, 67% paraplegic and 65% complete lesion.

Table 1 shows the results of the separate regression models. Age and lesion characteristics were not significantly related to ESE. From the potentially modifiable variables, only BMI and fatigue were significant determinants of ESE; a higher BMI and more fatigue were both related to lower ESE.

Conclusion

The relationships of body weight and fatigue to ESE seem to underscore the importance of weight and fatigue management during rehabilitation in persons with recent SCI. Age and lesion characteristics were unrelated to ESE. This suggests that, based on these characteristics, no subgroups could be identified which would need more attention in interventions targeting ESE in persons with recent SCI during inpatient rehabilitation.

Table 1. Separate regression models with exercise self-efficacy as dependent variable

	Exercise self-efficacy	
Independent variable	B	p
Age	0.02	0.72
Lesion level	-2.14	0.09
Motor completeness	1.10	0.38
BMI[1]	-0.28	0.03*
Peak oxygen uptake (L/min)[2]	1.70	0.28
Peak power output (Watt)[2]	0.04	0.07
Fatigue	-1.64	<0.01*
Pain[2]	-0.04	0.19

B=unstandardized regression coefficient
[1]corrected for lesion level and age
[2]corrected for lesion level
*Significant determinant

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Modifiable predictors of physical activity among mobility device users: A study of adults with spinal cord injury

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Abstract The purpose of this study was to identify modifiable, social cognitive variables that could help to explain differences in leisure time physical activity (LTPA) participation across manual wheelchair, power wheelchair, and gait aid users. A prospective study design was used. Participants were 503 adults (77% male; M age=47.9 $\pm$ 13.2) with an SCI (M years post injury = 15.6 $\pm$ 11.0), whose primary mode of mobility was a manual chair (56%), power chair (31%), or gait aid (13%). At baseline, participants completed measures of Theory of Planned Behaviour (TPB) constructs: attitudes toward LTPA, subjective norms for LTPA, perceived behavioural control over LTPA, and intentions to engage in LTPA. Six months later, participants' LTPA was assessed using the Physical Activity Recall Assessment for People with SCI (PARA-SCI). One-way ANOVAs revealed that, at baseline, power chair users had significantly weaker subjective norms, perceived behavioural control, and intentions to engage in LTPA than manual chair users. Gait aid users had poorer attitudes towards LTPA than manual chair users. Six months later, gait aid and power chair users reported significantly less min/day of LTPA than manual chair users (all *p*s < .05). Path analyses revealed that the TPB variables explained 8-14% of the variance in LTPA across the three groups. Among manual chair users, attitudes, subjective norms and perceived behavioural control all had significant indirect effects on LTPA. Among power chair users, attitudes and perceived behavioural control had significant indirect effects. Among gait aid users, only attitudes had significant indirect effects on LTPA. Together, these results suggest that poorer attitudes toward LTPA may partially explain why gait aid users are less active than manual chair users. As such, attitude-change interventions may be an effective LTPA-enhancing strategy for this subgroup. Likewise, a weaker sense of perceived control might help to account for weaker intentions and fewer min/day of LTPA among power chair than manual chair users. Power chair users may benefit from interventions designed to enhance their perceived control over LTPA.

Keywords Theory of Planned Behaviour; leisure time physical activity; attitudes; paraplegia; tetraplegia

Introduction

Population-based research has shown that adults with SCI who use a power wheelchair or a gait aid report significantly fewer minutes per day of leisure time physical activity (LTPA) than those who use a manual wheelchair (Martin Ginis et al., 2010). Given differences in physical functioning and impairment between those who can self-propel a wheelchair versus those who cannot, the higher levels of LTPA in manual versus power wheelchair users is not surprising. It is unclear, however, why those who can ambulate are less physically active than manual wheelchair users. One possibility is that ambulatory individuals with SCI experience unique psychosocial barriers to LTPA such as reduced opportunities for participation and perceptions of stigma (Papathomas & Smith, 2014). The purpose of the present study was to examine differences in social cognitive

predictors of LTPA across manual chair, power chair, and gait aid users. Detection of such differences is vital to developing LTPA-enhancing intervention strategies that are sensitive to the needs of users of different types of mobility devices.

Methods

Participant

This study was a secondary analysis of data collected in the Study of Health and Activity in People with Spinal Cord Injury (SHAPE-SCI; Martin Ginis et al., 2008). Participants were 503 men and women with an SCI (77% male; M age=47.9 $\pm$ 13.2) who completed baseline and 6-month assessments. Their primary mode of mobility was a manual chair (56%), power chair (31%), or gait aid (13%). On average, participants were 15.6 years post injury (SD = 11.0).

Measures and Protocol

At baseline, during a telephone-delivered interview, participants provided demographic and mobility device information, and completed standardized measures of social cognitive constructs drawn from the Theory of Planned Behaviour (attitudes, subjective norms, perceived behavioural control, and intentions for LTPA). Six months later, they completed the Physical Activity Recall Assessment for People with SCI (PARA-SCI; Martin Ginis et al., 2005).

Analyses

One-way ANOVAs were used to test for differences in the study measures as a function of mobility type. A series of path models were computed to examine the pattern of predictors of LTPA across the three types of mobility aid users.

Results

At baseline, gait aid users had poorer attitudes towards LTPA than manual chair users. Power chair users had significantly weaker subjective norms, perceived behavioural control, and intentions to engage in LTPA than manual chair users. Six months later, power chair and gait aid users reported significantly less LTPA than manual chair users. Path analyses showed that among manual chair users, attitudes, subjective norms and perceived behavioural control all had significant indirect effects on LTPA (mediated through intentions). Among power chair users, attitudes and perceived behavioural control had significant indirect effects. Among gait aid users, only attitudes had significant indirect effects on LTPA.

Table 1. Descriptive Statistics for Measures of the Theory of Planned Behaviour Constructs and Moderate-Heavy Leisure Time Physical Activity (LTPA)

Participants	Attitudes M (SE)	Subjective Norms M (SE)	Perceived Behav'l Control M (SE)	Intentions M (SE)	Min/day LTPA M (SE)
Manual Chair users (n = 284)	5.77[a] (.07)	5.96[a] (.08)	5.50[a] (.09)	5.14[a] (.12)	14.62[a] (1.36)
Power Chair users (n = 155)	5.55[ab] (.10)	5.68[b] (.11)	4.84[b] (.12)	4.61[b] (.16)	9.47[b] (1.83)
Gait Aid users (n = 63)	5.24[b] (.15)	5.68[ab] (.18)	5.45[ab] (.19)	4.96[ab] (.25)	8.23[b] (2.91)

Note. All values are adjusted for years post injury. Values with different superscripts are significantly different ($p < .05$)

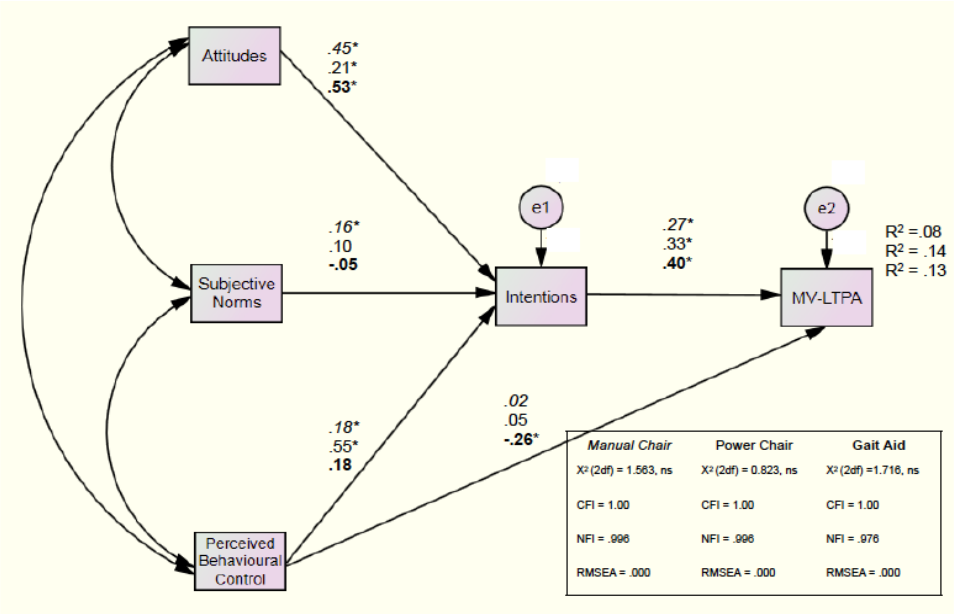

Figure 1. Path models showing standardized betas for users of *manual chairs*, power chairs and **gait aids**. *p < .05

Conclusion and discussion

Together, these results suggest that poorer attitudes toward LTPA may partially explain why gait aid users are less active than manual chair users. As such, attitude-change interventions (e.g., providing targeted information on the affective and instrumental benefits of LTPA) may be an effective LTPA-enhancing strategy for this subgroup. A weaker sense of perceived control might help to account for weaker intentions and fewer min/day of LTPA among power chair than manual chair users. Power chair users may benefit from interventions designed to enhance their perceived control over LTPA (e.g., development of plans and strategies to overcome barriers).

Acknowledgements

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Oral presentations
Thursday, April 24, 2014

Keynote lecture 5: Prof. Dr. J. Czerniecki

The Cost of Impaired Walking

Czerniecki J

Metabolic studies have been used to evaluate many different types of mobility, as well as, the underlying factors that contribute to the high metabolic energy expenditure of disabled gait, and the effects of therapeutic interventions on the efficiency of ambulation. Although metabolic studies have been used in a wide variety of disabled populations, this presentation will be focused primarily on the metabolic aspects of impaired walking in the amputee population. Many aspects of this discussion, however, can be translated into other patient populations. The potential utility of commonly used metabolic outcome variables will be reviewed along with their relationship to the clinical context of the amputee population. Special reference to the differences in the relative value of these studies to the study of the two primary amputee subpopulations; the younger traumatic amputee and the dysvascular elderly amputee, will be made. The contribution of metabolic studies to the evaluation of the clinical effectiveness of prosthetic componentry, especially that of novel prosthetic knees and foot/ankle mechanisms will also be reviewed. Finally, the critical question of the value of metabolic outcome studies and their relative contribution to understanding pathophysiologic mechanisms of gait after amputation and the clinical care of this population will be discussed.

Oral presentations
Thursday, April 24, 2014

Session 7: Physical Activity 2

A comparison of wheeling: Activity of daily living versus leisure-time physical activity

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Abstract Moderate-heavy intensity (MH) physical activity is associated with numerous physical health and psychosocial benefits for people with spinal cord injury (SCI). The purpose of this paper was to: (1) examine how people with SCI accrue MH-wheeling and (2) examine the correlates of wheeling as an activity of daily living (ADL) versus wheeling as a leisure-time physical activity (LTPA). *Methods:* Three hundred and eighty-nine community-dwelling people with SCI who use a manual chair as a primary mode of mobility were recruited (77.9% male; age =45.1 yrs ±12.1; years post-injury =16.4 yrs ±10.5). Cross-sectional demographic and health status data were collected through a telephone interview. MH-wheeling was measured using the Physical Activity Recall Assessment for People with SCI; wheeling was coded as an ADL or LTPA. *Results:* One hundred and fifty-three (39.3%) participants accrued any MH-ADL wheeling while only 52 (13.4%) accrued any MH-LTPA wheeling. However, those who engaged in MH-ADL wheeling accrued significantly less min/day of MH wheeling (M= 13.3 min/day ±25.6) than those who reported accrued minutes of MH wheeling as an LTPA (M=22.8 min/day ±19.8; t=2.42, p=.016). In a regression analysis, injury severity (B=0.21, p=.006) was the only significant predictor of MH-ADL wheeling. In the regression analysis for MH-LTPA wheeling, education (B=0.16, p=.008), marital status (B=.23, p<.001), health status (B=0.13, p=.015), and perceived health (B=0.14, p=.020) were significant predictors while gender (B=0.10, p=.073) and injury severity (B=0.11, p=.087) were marginally significant. *Conclusion:* People who engage in MH-LTPA wheeling accrue nearly twice as much daily activity as those who engage only in MH-ADL wheeling. However, promoting MH-ADL wheeling in addition to LTPA may be an effective physical activity and health-enhancing strategy for the SCI population, given that factors that may inhibit LTPA (low education, lack of partner support, poorer health status) are not associated with MH-ADL wheeling.

Keywords wheeled mobility, daily physical activity, spinal cord injury

Introduction

After a spinal cord injury (SCI), changes to body composition and metabolism lead to an elevated risk for chronic diseases, including cardiovascular disease (CVD) and Type II diabetes. In addition to body composition and metabolic changes, many people with SCI either reduce or completely stop participating in physical activity (Buchholz et al., 2003). This change is troubling given the association between decreased physical activity and increased risk indicators for chronic disease such as higher BMI and insulin resistance (Buchholz et al., 2009). Individuals who engage in wheeling (e.g., self-propulsion of the wheelchair) as an activity of daily living (ADL) have lower LDL and total cholesterol (Hetz et al., 2009) than those who do not accrue any ADL wheeling. Thus, promoting wheeling as a method of active transportation, in addition to promoting leisure-time physical activity (LTPA), may be a promising avenue for enhancing moderate and

heavy intensity (MH) physical activity. The purpose of this paper was to explore the predictors of these two types of wheeling.

Methods

A subsample of participants from the Study of Health and Activity in People with Spinal Cord Injury (Martin Ginis et al., 2008) were included. For inclusion, participants were required to be community-dwelling people with traumatic SCI who use a manual chair as a primary mode of mobility. Three hundred and eighty-nine participants met these criteria (77.9% male; age =45.1 yrs ±12.1; years post-injury =16.4 yrs ±10.5). Participants completed demographic and health status questionnaires by telephone with trained interviewers. Average daily MH-wheeling was measured using the Physical Activity Recall Assessment for People with SCI (Latimer et al., 2006); wheeling was coded as an ADL or LTPA. Data were analyzed using a hierarchical linear regression to predict each type of wheeling. Demographic variables including age, sex, and injury severity were entered in the first step and health status variables were entered in the second step.

Results

One hundred and fifty-three (39.3%) participants accrued minutes of MH-ADL wheeling (M= 13.3 min/day ±25.6) while 52 (13.4%) participants reported engaging in MH-LTPA wheeling (M=22.8 min/day ±19.8). Although fewer participants reported engaging in MH-LTPA wheeling, they were engaged in MH-wheeling for a significantly longer duration than those who accrued minutes of MH-ADL wheeling ($t=2.42$, $p=.016$). The regression analysis revealed distinct predictors for the two types wheeling. For MH-ADL wheeling, injury severity ($B=0.21$, $p=.006$) was the only significant predictor. For MH-LTPA wheeling, marital status ($B=.23$, $p<.001$), education ($B=0.16$, $p=.008$), health status ($B=0.13$, $p=.015$), and perceived health ($B=0.14$, $p=.020$) were significant predictors while gender ($B=0.10$, $p=.073$) and injury severity ($B=0.11$, $p=.10$) were marginally significant predictors.

Conclusion and discussion

People who engage in MH-LTPA wheeling accrue nearly twice as much daily activity as those who engage only in MH-ADL wheeling. However, promoting MH-ADL wheeling in addition to LTPA may be an effective physical activity and health-enhancing strategy for the SCI population, given that factors that may inhibit LTPA (low education, lack of partner support, poorer health status) are not associated with MH-ADL wheeling. As such, it is important to encourage both forms of wheeling among this population.

Table 1. Descriptive statistics and regression models for predicting MH-wheeling as an ADL vs. LTPA

Variable	Mean (SD),	ADL model			LTPA model		
Step 1	n (%)	B	SE B	β	B	SE B	β
Age	45.06 (12.01)	-.075	.092	-.051	-.058	.054	-.066
Sex (% men)	303 (77.89%)	-1.61	2.26	-.038	2.60+	1.34	.10+
Education[a]							
High school	126 (32.39%)	-2.60	2.93	-.070	2.79	1.74	.124
College	100 (25.71%)	-1.26	3.01	-.031	1.19	1.78	.049
University	72 (18.51%)	2.33	3.21	.052	.47	1.90	.017
Postgraduate	25 (6.43%)	6.19	4.25	.088	6.93**	2.52	.16**
Ethnicity[b]							
Native Canadian	10 (2.57%)	-.84	5.73	-.008	.37	3.40	.006
Black	11 (2.83%)	-2.08	5.55	-.020	-.47	3.30	-.007
Asian	6 (1.54%)	-6.95	7.35	-.050	-1.40	4.36	-.016
Other	11 (2.83%)	1.17	5.36	.011	-1.87	3.18	-.030
Marital Status[c]							
Common Law	21 (5.40%)	1.57	4.23	.020	11.03**	2.51	.233**
Married	175 (44.99%)	2.98	2.18	.085	1.04	1.29	.049
Divorced	45 (11.57%)	.57	3.11	.010	-.62	1.85	-.019
Injury Severity[d]							
C1-C4, ASIA A-C	10 (2.57%)	3.03	6.28	.026	-1.09	3.72	-.016
C5-C7, ASIA A-C	98 (25.19%)	8.27**	2.92	.206**	2.72+	1.72	.112+
T1-S5, ASIA A-C	213 (54.76%)	2.28	2.56	.065	2.12	1.50	.099
Years Post-Injury	16.35 (10.59)	-.11	.096	-.063	.051	.057	.051
Model Significance, R^2		$F(17,357)=1.47$, 6.5%			$F(17,359)=2.34$**, 5.7%		
Step 2							
Pain	5.49 (2.27)	.68	.45	.087	-.25	.26	-.054
Functional Impairment	4.95 (1.31)	.14	.83	.011	.39	.49	.048
Perceived Health	4.10 (4.13)	.096	.26	.023	.35**	.15	.14**
Health Status	6.67 (1.56)	.88	.67	.078	.90*	.40	.13*
Model Significance, ΔR^2		$F(21,353)=1.355$, 7.5%			$F(21,355)=2.39$**, 7.2%		

+p<.10, *p<.05, **p<.01, [a]Referent category is "Other", [b]Referent category is "Caucasian", [c]Referent category is "Single", [d]Referent category is "Asia D

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Longitudinal Relationship between Fitness, Walking-related Physical Activity, Mobility and Fatigue in Children with Cerebral Palsy

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Abstract The purpose of this study was to determine the longitudinal relationship between physical fitness, walking-related physical activity (PAL), mobility capacity and fatigue in children with cerebral palsy (CP). Forty-six children with a bilateral (N=24) or a unilateral spastic CP (N=22), aged 7-13 years, participated in aerobic and anaerobic fitness measurements on a cycle ergometer and isometric and functional muscle strength tests. Mobility capacity was assessed with the gross motor function measure (GMFM) and the 1-min walk test. Walking-related PAL was measured in steps per minute using an ankle-worn accelerometer (StepWatch^{TM}) for 1 week. Fatigue was determined via self-reports using the PedsQL multidimensional fatigue scale. Longitudinal relationships (change over one year) were determined using random coefficient analysis ($p<0.05$). Anaerobic fitness ($p<0.001$) and isometric muscle strength ($p<0.05$) were determinants for mobility capacity in children with bilateral CP, but not in those with unilateral CP. In children with bilateral CP, all fitness parameters showed a positive, significant relationship to walking-related PAL ($p<0.05$), whereas no relationship between physical fitness and walking-related PAL was seen in children with unilateral CP. No clinically relevant relationship between physical fitness and fatigue was found. The strong longitudinal relationship between fitness, mobility capacity and walking-related PAL in children with bilateral CP indicates that increasing physical fitness might be beneficial for mobility capacity and walking-related PAL in children with bilateral CP, while this is less likely for children with unilateral CP. Interventions aimed at improving mobility capacity and PAL may be differently targeted in children with either bilateral or unilateral CP.

Keywords Physical fitness; physical activity; mobility; cerebral palsy; children

Introduction

Children with cerebral palsy (CP) are reported to have decreased levels of physical fitness, impaired mobility and physically inactive lifestyles. It has been suggested that children with CP are trapped in a vicious circle of low physical fitness, experience of fatigue during physical activities leading to inactivity, which results in deconditioning and a further decrease in levels of physical activity.(Fowler, Kolobe et al., 2007) Interventions aimed at improving fitness, physical activity and mobility through fitness training did not lead to higher levels of physical activity.(Van Den Berg-Emons, van Baak et al., 1998) Apparently, a better understanding of the mechanisms between fitness and physical activity is required in order to target interventions. Therefore, the purpose of this study was to determine the longitudinal relationship between physical fitness, walking-related physical activity (PAL), mobility capacity and fatigue in children with cerebral palsy (CP).

Methods

Participants

Forty-six children with a bilateral (N=24) or a unilateral spastic CP (N=22), aged 7-13 years, participated in measurement sessions at baseline, after 4, 6 and 12 months.

Measurements

Aerobic and anaerobic fitness measurements on a cycle ergometer were performed. VO_2peak as determined with a progressive maximal cycle ergometer test was found to a reliable measure for aerobic fitness with an ICC of 0.94 and a smallest detectable change of 5.72 $ml \cdot kg^{-1} \cdot min^{-1}$. (Brehm, Balemans et al., 2014) Mean power over 20 s (p20mean) was measured as an estimate of anaerobic or sprint power and showed good reliability with ICCs of 0.96-0.99 and SEMs of 0.148-0.270 $W \cdot kg^{-1}$.(Dallmeijer, Scholtes et al., 2013) Isometric muscle strength of the knee extensors and hip abductors of the most involved limb was measured using hand-held dynamometry. Test-retest reliability of isometric muscle strength tests was found to be good with ICC's of > 0.82 and SEMs of 0.55 $N \cdot kg^{-1}$ (knee extensors) and 1.21 $N \cdot kg^{-1}$ (hip abductors).(Willemse, Brehm et al., 2013) Functional muscle strength tests were also performed. Mobility capacity was assessed with the gross motor function measure (GMFM) and the 1-min walk test. Walking-related PAL was measured in steps per minute using an ankle-worn accelerometer (StepWatch^{TM}) for 1 week. Fatigue was determined via self-reports using the PedsQL multidimensional fatigue scale.

Statistics

Longitudinal relationships (change over one year) between fitness components, mobility capacity and physical activity were determined using random coefficient analysis ($p<0.05$). Effect modification of unilateral or bilateral involvement and level of gross motor function was investigated.

Results

Multivariable analysis showed that anaerobic fitness ($p<0.001$) and isometric muscle strength ($p<0.05$) were significant determinants of GMFM and 1 min walking distance in children with bilateral CP, but not in children with unilateral CP. In children with bilateral CP, all fitness parameters showed a positive, significant relationship to walking-related PAL ($p<0.05$), whereas no relationship between physical fitness and walking-related PAL was seen in children with unilateral CP. No clinically relevant relationship between physical fitness and fatigue was found.

Conclusion and discussion

The strong longitudinal relationship between fitness, mobility capacity and walking-related PAL in children with bilateral CP indicates that increasing physical fitness might be beneficial for mobility capacity and walking-related PAL in children with bilateral CP, while this is less likely for children with unilateral CP. The lack of relationship between physical fitness and self-reported fatigue in

all children with CP does not support the existence of the assumed vicious cycle of increased fatigue due to low fitness levels. The association between fatigue and fitness should be further explored in future research. Interventions aimed at improving mobility capacity and PAL may be differently targeted in children with either bilateral or unilateral CP.

Acknowledgements

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Handcycling in Switzerland: A cross-sectional analysis of the population with spinal cord injury

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Abstract The handbike is an effective device for mobility and exercise of the upper extremity in persons with spinal cord injury (SCI). Its use may enhance overall fitness and lower the risk of secondary health conditions. The aim of this study was to investigate handbike use in Switzerland and to evaluate factors that may facilitate or restrain handcycling. In a cross-sectional and population-based survey we identified handbike users, studied factors possibly associated with handbike use, and examined reasons for not using a handbike. Included were persons 16 years or older, who were diagnosed with traumatic or non-traumatic SCI, and who were permanently residing in Switzerland. Data were collected between 2011 and 2013 by self-report. Basic descriptive statistics as well as multivariable logistic regression analysis were used to evaluate associations of handbike use with socio-demographic and socio-economic factors and SCI characteristics. 1549 persons participated in the study, whereof 350 persons (22.6%) were handbike users. The probability of handbike use was highest in persons with the following characteristics: being male, having a complete paraplegic lesion, speaking German (vs. French/Italian) and having a middle net income. Handbike use declined with age, but was not associated with education or cause of injury. The most frequently mentioned reasons for not using a handbike were “no interest” (26%), “cannot use the handbike due to disability” (20%), “I do not know the handbike” (19%) and “too expensive” (14%). This representative and up-to-date study revealed that a substantial proportion of persons with SCI living in Switzerland routinely use the handbike. Future activities that aim to further promote handcycling should emphasize the health benefits of handcycling and reduce financial barriers to its usage, with a special focus on the female population and the French and Italian part of Switzerland.

Keywords Handcycling, spinal cord injury, community survey, demographic factors, barriers

Introduction

Use of the handbike enables persons with spinal cord injury (SCI) to engage in a healthy and more physically active lifestyle, which may in turn increase participation, social integration and quality of life (Stevens, Caputo et al. 2008). To effectively promote and support handcycling as a means to increase physical activity, overall health and wellbeing in the SCI community we need detailed information regarding the patient traits as well as contextual facilitators and barriers that influence handbike-use.

The aim of this study is to examine the handbike use in Switzerland. Specifically, we will 1) compare demographic and socioeconomic factors as well as lesions characteristics between users and non-users of the handbike and 2) evaluate barriers for handcycling among non-users.

Methods

Study design and sample

Data used for this study originate from a community survey (SwiSCI cohort study) which includes persons (16 years or older) who were diagnosed with traumatic or non-traumatic SCI, and who are permanently residing in Switzerland. People with congenital conditions leading to SCI, with new SCI in the context of palliative care, with neurodegenerative disorders, and with Guillain-Barré syndrome were excluded. 3144 eligible subjects were identified for participating in the community survey and thereof 1549 subjects answered the basic questionnaire between late 2011 and early 2013.

Variables and statistical analysis

All variables were assess by self-report. Subjects were classified into 'handbike users' and 'non-users' by asking the question "Are you using a handbike?". The assessed demographic and socioeconomic factors, as well as lesion characteristics are listed in Table 1. The non-users were asked for the reasons why they don't use a handbike.

For data analysis, basic descriptive statistics were used to describe the study population. A multivariable logistic regression analysis was used to evaluate associations of handbike use with demographic and socioeconomic factors and SCI characteristics.

Results

From the 1549 people that participated in the study were 22.6% handbike user (350 subjects). Participants' characteristics are shown in table 1 for all participants and stratified by handbike use.

Handbike use was associated with gender, age, income, language and lesion characteristics.

The odds (odds ratio; 95% confidence interval) of handbike use were highest in persons with the following characteristics: being male (1.49; 1.07-2.06, compared to women), having a complete paraplegic lesion (4.75; 3.35-6.73, compared to incomplete paraplegia), speaking German (2.63; 1.86-3.73, compared to French/Italian) and having a middle net household income (1.71; 1.19-2.46, compared to low income). Handbike use declined with age (0.96; 0.95-0.97, per year of age), but was not associated with education or cause of injury.

The most frequently mentioned reasons for not using a handbike were "no interest" (26%), "cannot use the handbike due to disability" (20%), "I do not know the handbike" (19%) and "too expensive" (14%).

Table 1. Demographics, socioeconomic factors and lesion characteristics of all participants as well as percentage of handbike users per variable.

		Overall n (N = 1549)	Handbike User
Sex	male	1107	25.3%
	female	442	17.7%
Age	median (years)	52	46
	16-30 years	129	27.6%
	31-45 years	337	34.1%
	46-60 years	571	24.9%
	61-75 years	378	12.8%
	76+ year	94	2.3%
Education	compulsory	143	13.1%
	vocational	377	19.1
	secondary	721	25.6
	university	276	28.2
	missing	32	13.8
Net equivalent household income	low	584	17.1
	middle	338	31.1
	high	459	25.7
	missing	168	20.1
Language	German	1088	27.0
	French	391	13.3
	Italian	70	17.9
Lesion characteristics	PP, incomplete	577	12.8
	PP, complete	486	42.4
	TP, incomplete	314	11.7
	TP, complete	160	25.0
	missing	12	0.0
Cause of injury	traumatic	1202	26.5
	non-traumatic	332	12.0
	missing	15	0.0

Conclusion and discussion

This study revealed that a substantial proportion of persons with SCI living in Switzerland routinely use the handbike. The handbike user group in Switzerland is considerably large, also in comparison with other European countries (Biering-Sorensen, Hansen et al. 2004, Valent, Dallmeijer et al. 2007).

There is, however, still scope to enlarge the handbike user population. Future activities that aim to further promote handcycling should emphasize the use for leisure activities and the health benefits of handcycling and reduce financial barriers to its usage. It is recommended to do this with a special focus on women, the older population and the French and Italian speaking part of Switzerland.

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Tailwind - Handcycling for children with special needs

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Abstract *Purpose:* The purpose of this study was to evaluate the influence of a six-month mobility training program in handcycling on self-confidence, mobility and time being active per week in children using a wheelchair for all day mobility. *Methods:* Twenty-six children (age 7-17 years old) using a wheelchair as a mobility device, without any handcycling experiences were recruited at seven schools for the study (schools for special educational needs; all children were physically handicapped sixteen with an additional intellectual impairment). Each child was equipped with an adaptive handcycle given to the schools as a permanent gift. Information on handcycling use, safe behaviour on the road, training and the benefit of physical activity was given to the children during a promotion day at school and, following that during regular physical education (twice a week). Psychological questioners were done starting with the mobility training (pre) and after six month (post). *Results:* Self reported values of self-confidence increased by 53.3 %; activity with the family during weekends by 40.1 % physical activity by 54.6 % and feeling comfortable and health by 45.5 %. *Conclusions*: Handcycling had a positive effect on self-confidence, mobility and time being active per week in children with physical and intellectual impairments.

Oral presentations
Thursday, April 24, 2014

Session 8: Training & Intervention

Effects of hybrid versus handcycle exercise on cardiovascular risk factors in spinal cord injury

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Abstract The purpose of this study was to examine the effects of a hybrid cycle versus handcycle exercise program on metabolic syndrome (MetS), inflammatory status and visceral adiposity in people with long-term spinal cord injury (SCI). Nineteen inactive wheelchair-dependent individuals (aged 28-65 years; age at onset SCI≥18) with paraplegia or tetraplegia ≥9 years have completed this 16-wk multicenter randomized-controlled trial. The hybrid group (N=9) performed a hybrid cycle (functional electrical stimulation (FES)-induced leg exercise combined with voluntary arm exercise) training program, while the handcycle group (N=10) performed a handcycle program. Both groups trained twice a week, 30 min at 70% heart rate reserve. Outcome measures obtained pre and post the program were MetS components (waist circumference (WC), systolic (SBP) and diastolic (DBP) blood pressure, high-density lipoprotein cholesterol (HDL-C), triglycerides (TG) and insulin resistance (glucose, insulin and homeostasis model assessment-estimated insulin resistance (HOMA-IR)), inflammatory status (C-reactive protein (CRP), interleukin (IL)-6 and IL-10, and visceral adiposity (trunk and android fat). Differences between pre and post measurements were examined using a two-factor mixed measures ANOVA. Overall significant reductions were found for WC (3.5%, p=0.001), DBP (7%, p=0.03), insulin (26%, p=0.004), HOMA-IR (26%, p=0.006), CRP (16%, p=0.05), IL-6 (26%, p=0.04), IL-6/IL-10 ratio (32%, p=0.03), trunk (3.6%, p=0.04) and android (4.7%, p=0.02) fat percentage. No significant main effects for time were observed for SBP, TG, HDL-C, glucose, IL-10, and trunk and android fat mass. For all outcome measures, there were no significant differences between groups. It can be concluded that hybrid cycling and handcycling have similar beneficial effects on different MetS components, inflammatory status and visceral adiposity, indicating that there were no additional benefits of FES-induced leg exercise above handcycle training alone.

Keywords Metabolic Syndrome, insulin resistance, inflammation, adiposity, paralysis, electric stimulation

Introduction

Cardiovascular disease (CVD) is the leading cause of mortality in people with spinal cord injury (SCI) (Garshick, Kelley et al, 2005). The seriously inactive lifestyle observed in many individuals with SCI is strongly associated with a high prevalence of CVD risk factors, such as metabolic syndrome (MetS), chronic low-grade inflammation and visceral adiposity (Washburn & Figoni, 1998). To date, there is insufficient knowledge about the effectiveness of different training interventions on CVD risk factors in people with long-term SCI. Therefore, the aim of this study was to examine the effects of a 16-wk hybrid cycle versus handcycle training program on MetS components, resting inflammatory status and visceral adiposity in people with long-term SCI.

Methods

Participants

Nineteen (N=19) physically inactive individuals (aged 28-65 years; age at onset SCI ≥ 18 years) with SCI ≥ 9 years have completed this study. Individuals were eligible for inclusion if they were wheelchair-dependent, and if they had a spastic paralysis and no or limited sensation in the lower extremity. Individuals were excluded if they had contraindications for physical training and testing, or psychiatric problems that could interfere with study participation. Individuals were also excluded if they had plans to change current lifestyle habits, or if they had insufficient knowledge of the Dutch language to understand the purpose and protocol of the study.

Design

This study was a 16-wk randomized-controlled trial performed in two rehabilitation centers. Within each rehabilitation center, block randomization was used to assign the participants to either the experimental group (hybrid cycle group; functional electrical stimulation (FES)-induced leg exercise combined with voluntary arm exercise) or control group (handcycle group; voluntary arm exercise alone). Both groups trained twice a week, 30 min at 70% heart rate reserve. Outcome measures obtained pre and post the program were MetS components (waist circumference (WC), systolic (SBP) and diastolic (DBP) blood pressure, high-density lipoprotein cholesterol (HDL-C), triglycerides (TG) and insulin resistance (glucose, insulin and homeostasis model assessment-estimated insulin resistance (HOMA-IR)), inflammatory status (C-reactive protein (CRP), interleukin (IL)-6 and IL-10, and visceral adiposity (trunk and android fat).

Statistics

Differences between pre and post exercise training measurements were examined using a two-factor (time x group) mixed measures ANOVA. Significance was set a priori at $p \leq 0.05$.

Results

CVD risk factors

As shown in Table 1, overall significant reductions were found for WC (3.5%), DBP (7%), insulin (26%), HOMA-IR (26%), CRP (16%, p=0.05), IL-6 (26%), IL-6/IL-10 ratio (32%), and trunk (3.6%) and android (4.7%) fat percentage. No significant main effects for time were observed for SBP, TG, HDL-C, glucose, IL-10, and trunk and android fat mass. For all outcome measures, there were no significant differences between groups.

Table 1. Metabolic syndrome, inflammatory status and visceral adiposity

	Whole group		HYB		HC		P values	
MetS components (N: 9 HYB, 10 HC)	Pre	Post	Pre	Post	Pre	Post	Main effect time	Inter-action
WC (cm)	90.7 (2.8)	87.5 (2.4)	91.8 (4.7)	87.8 (4)	89.7 (3.5)	87.3 (2.9)	0.001	0.38
SBP (mm Hg)	116 (3)	120 (4)	112 (6)	117 (9)	119 (4)	123 (3)	0.18	0.92
DBP (mm Hg)	71 (2)	66 (3)	69 (3)	63 (4)	72 (3)	70 (4)	0.03	0.31
TG (mmol·L^{-1})	1.4 (0.1)	1.3 (0.1)	1.7 (0.2)	1.4(0.2)	1.2 (0.2)	1.1 (0.1)	0.15	0.49
HDL-C (mmol·L^{-1})	1.24 (0.1)	1.30 (0.1)	1.09 (0.11)	1.20 (0.11)	1.38 (0.16)	1.39 (0.17)	0.3	0.35
Glucose (mmol·L^{-1})	5.5 (0.2)	5.4 (0.2)	5.7 (0.3)	5.8 (0.4)	5.3 (0.2)	5.1 (0.2)	0.68	0.17
Insulin (pmol·L^{-1})*	63.6 (6.9)	47.4 (6)	72.7 (10.6)	56.0 (9.5)	54.6 (8.5)	40.5 (7.3)	0.004	0.65
HOMA-IR*	2.3 (0.3)	1.7 (0.3)	2.8 (0.5)	2.2 (0.6)	1.9 (0.3)	1.3 (0.2)	0.006	0.44
Inflammatory status (N: 7 HYB, 9 HC)								
CRP (mg·L^{-1})	3.32 (1.05)	2.79 (1.03)	3.91 (1.75)	3.20 (1.68)	2.86 (1.36)	2.47 (1.38)	0.05	0.92
IL-6 (pg·mL^{-1})	2.45 (0.49)	1.81 (0.31)	2.51 (0.91)	1.88 (0.58)	2.40 (0.57)	1.76 (0.36)	0.04	0.93
IL-10 (pg·mL^{-1})	0.27 (0.02)	0.31 (0.03)	0.29 (0.03)	0.29 (0.04)	0.26 (0.02)	0.32 (0.05)	0.29	0.16
IL-6/IL-10 ratio	9.52 (2.13)	6.55 (1.49)	8.07 (2.33)	7.23 (2.47)	10.65 (3.40)	5.96 (1.92)	0.04	0.54
Visceral adiposity (N: 5 HYB, 5 HC)								
Trunk fat (kg)	11.5 (1.2)	11 (1.3)	9.7 (1.6)	9.2 (1.5)	13.2 (1.7)	12.7 (1.7)	0.2	0.99
Trunk fat (%)	30.6 (2)	29.5 (2)	27.5 (2.7)	25.9 (2.3)	33.7 (2.5)	33.0 (2.5)	0.04	0.41
Android fat (kg)	2.3 (0.3)	2.3 (0.3)	2.0 (0.4)	1.9 (0.4)	2.6 (0.4)	2.6 (0.4)	0.47	0.68
Android fat (%)	36 (2.4)	34.3 (2.2)	33.4 (2.9)	31.3 (2.6)	38.6 (3.7)	37.2 (3.3)	0.02	0.52

Values are mean ± standard error . HYB, hybrid cycle group; HC, handcycle group; MetS, metabolic syndrome; Δ, pre-post difference; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, homeostasis model assessment-estimated insulin resistance; CRP, C-reactive protein; IL-6, interleukin-6; IL-10, interleukin-10. *Analysis was performed on N: 8 HYB, 8 HC.

Conclusion

Hybrid cycling and handcycling have similar beneficial effects on different MetS components, inflammatory status and visceral adiposity, indicating that there were no additional benefits of FES-induced leg exercise above handcycle training alone.

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Activity-based therapy and current guidelines for exercise in SCI individuals

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Abstract Activity-based therapy (ABT) is a modality of rehabilitation intended to improve functional outcomes after spinal cord injury (SCI). ABT is characterized by long-duration sessions (often > 2 h) employing numerous whole-body repetitive movements varying from light to vigorous exercise intensities. The purpose of this study was to investigate whether ABT met current guidelines on quantity and quality of exercise for developing cardiorespiratory fitness in individuals with chronic SCI. Twenty-one individuals (age 33 ± 13 y; SCI lesions: 16 C4-C8, 5 T1-L1) attended a community-based ABT program in Sydney and Melbourne. All underwent an arm crank maximal-effort aerobic fitness assessment and their ABT activities were assessed in terms of intensity and weekly duration over a two-week observation period. Heart rate reserve (HRR), estimated VO_2reserve (VO_2R), RPE and weekly accumulated MET-minutes for the group were compared to current ACSM exercise guidelines. For ACSM recommendations based on percent of HRR, seven of 21 individuals achieved “moderate” exercise > 150 min•week^{-1} (mean: 115 ± 66 min•week^{-1}; p>0.05) during ABT. For guidelines based on estimated percent VO_2R, 10 individuals achieved “moderate” exercise intensity > 150 min•week^{-1} (mean: 146 ± 115 min•week^{-1}; p>0.05). Twelve of 21 individuals achieved >500 MET-minutes of exercise over the 2-week observation period (mean: 482 ± 247 MET-minutes•week^{-1}; p>0.05). There were no clear patterns of participants who achieved current exercise guidelines based on their lesion level and degree of lesion severity. For 7-12 SCI participants in the current study, an activity-based therapy program intended for neurological improvement and functional outcomes also produced sufficient exercise intensity for appropriate duration to meet current HRR, VO_2R, RPE and MET-minutes ACSM guidelines for cardiorespiratory fitness.

Keywords Spinal cord injury, exercise, physical activity guidelines, activity therapy

Introduction

For most people with a spinal cord injury (SCI), decreased motor ability and wheelchair confinement leads to an increase in sedentary behaviors (Buchholz, McGillivray et al. 2003). Post-traumatic reduction of physical activity has been linked to negative health sequelae after SCI, such as cardiovascular disease, diabetes mellitus and visceral obesity, which are all much higher in this population than in their able-bodied counterparts (Edwards, Bugaresti et al. 2008).

Recently, rehabilitation therapy after SCI has incorporated central nervous system neuroplasticity using intense ‘task-specific training’ in an attempt to improve recovery (Behrman, Bowden et al. 2006). This method of rehabilitation has become known as ‘*activity-based therapy*’ (ABT), although some authors employ different phases with similar clinical meaning. ABT has become popular as a method of ongoing rehabilitation post-hospital treatment and has even been recently integrated into some hospital in-patient programs. It is characterized by long-duration sessions

(often > 2 h) employing numerous whole-body repetitive movements varying from light to vigorous exercise intensities. This study investigated whether ABT met current guidelines on quantity and quality of exercise for developing cardiorespiratory fitness in individuals with chronic SCI.

Methods

Participants

Twenty-one individuals (age 33 ± 13 y; 16 ♂, 5 ♀; SCI lesions: 16 C4-C8, 5 T1-L1) attended a community-based ABT program ("Walk On") in Sydney and Melbourne, Australia. Participants had been enrolled in the Walk On (WO) program for 11.4 ± 9.0 mo. Participants self-selected their weekly attendance pattern between 1 to 5 sessions per week.

Variables

The following variables were measured:

- VO_2rest, HRrest, VO_2peak, HRpeak and RPE were derived before and during an arm crank maximal-effort aerobic fitness assessment using metabolic measurement (COSMED K4b2 system)
- Heart rate reserve (HRR), VO_2reserve (VO_2R) were estimated from HRrest, VO_2rest, HRpeak, VO_2peak and individually-derived HR-VO_2 relationships during submaximal steady-state arm cranking exercise.
- HR was collected and stored at 1 s intervals (Polar Electro RS800CX heart rate monitor), during WO therapy, and HR and RPE were averaged over the various components of a ~2-h therapy session. Calculated average %HRpeak, %HRR, %VO_2R, RPE and weekly accumulated MET-min were ensemble-averaged over the number of sessions each individual attended over a two week observation period.

Statistics

Frequencies analysis and one-sample t-tests against HRpeak, %HRR, %VO2R and RPE ‘set points’ for current American College of Sports Medicine (ACSM) exercise guidelines were conducted using SPSS™ 21. Analyses were considered statistically significant at $p<0.05$.

Results

The participants arm cranking VO_2peak was 13.8 ± 4.7 ml•kg^{-1}•min^{-1} achieved at 39 ± 16 W of power output, and there were no significant differences between paraplegics and tetraplegics.

Although the average weekly ABT therapy time was greater than 250 min, only self-reported RPE>3 exceeded the 150 min·week^{-1} criterion, meeting that ACSM guideline for the group (Table 1). For guidelines based on estimated percent %VO_2R, ten individuals achieved “moderate” exercise intensity > 150 min•week^{-1} (mean: 146 ± 115 min•week^{-1}; $p>0.05$).

Twelve of 21 individuals achieved >500 MET-minutes of exercise per week over the 2-week observation period (Figure 1; mean: 482 ± 247 MET-minutes•week^{-1}; $p>0.05$). An additional 3 individuals were within 100 MET-min•week^{-1} of the minimum criterion.

Discussion and Conclusion

This study investigated whether ABT, with its primary purpose to promote neurological improvement and enhance functional outcomes after chronic SCI, also met current ACSM

guidelines for developing cardiorespiratory fitness. For 5-12 SCI participants in the current study, ABT produced sufficient exercise intensity of an appropriate duration to meet current %HRpeak, %HRR, %VO_2R, RPE and MET-min recommendations on quantity and quality of exercise for maintaining cardiorespiratory fitness. Six of 9 individuals who did not achieve at least 500 MET-minutes•week^{-1}, attended less than three times weekly, and frequency of ABT was the strongest ‘predictor’ for achieving the ACSM guidelines. Conversely, there were no clear patterns emergent from severity of SCI, lesion level or gender in relation to meeting the minimum dose-potency of aerobic exercise.

This study concluded that activity-based therapy, of long duration daily sessions (>2 h) but low-moderate exercise intensity, can also meet current guidelines on quantity and quality of exercise for developing cardiorespiratory fitness in some individuals with chronic SCI. However, there must be a minimum frequency of weekly exercise (three times per week) for this to be achieved.

Table 1. Achieving ACSM Guidelines for “moderate” exercise for HRpeak, HRR%, VO_2R and RPE

ACSM Guideline for “moderate” exercise intensity	Number Achieving Guidelines (/21)	Average time achieved @ ACSM “moderate” exercise intensity (min/week)	Significance
> 150 min•week^{-1} above 64% HRpeak	5	100.1 ± 58.8	n.s
> 150 min•week^{-1} above 40% HRR	7	115.5 ± 66.2	n.s.
> 150 min•week^{-1} above 40%VO_2R	10	146.9 ± 114.8	n.s
> 150 min•week^{-1} above 3 RPE	12	200.4 ±102.5	0.03

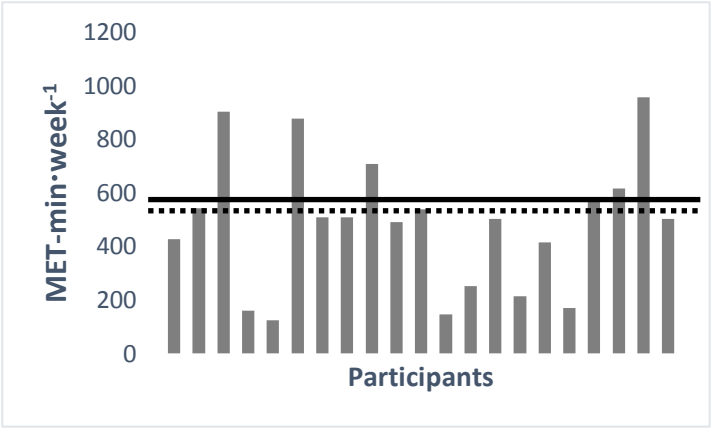

Figure 1. Achieving ACSM Guidelines for “moderate” exercise of 500-1000 MET-min per week. Solid line denotes 500 MET-min·week^{-1}. Dashed line denotes group mean 482 ± 247 MET-min per week

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Effectiveness of a lifestyle intervention in adolescents and young adults with cerebral palsy

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Abstract *Introduction*: Research has shown that persons with cerebral palsy have low levels of physical activity and fitness. During adolescence, there are many changes in life that affect adult lifestyle. Therefore, applying lifestyle programmes to increase daily physical activity and fitness seem beneficial at this age. *Methods:* Fifty-seven adolescents and young adults with spastic cerebral palsy (GMFCS I-IV) were recruited from hospitals and rehabilitation centers in the Netherlands. Participants were randomly assigned to either an intervention or control-group. The control-group received no intervention. The intervention-group participated in a lifestyle programme and consisted of individual counseling on daily physical activity and sports participation. Physical fitness training was offered during the first 3 months of the intervention. Participants were measured prior, directly after and 6 months after starting the intervention. Peak oxygen uptake was measured during a maximal exercise test on a cycle ergometer. Physical activity was measured with an accelerometry based activitymonitor. GEE-analysis was used to examine longitudinal effects of the intervention. *Results:* No effects over time were found for daily physical activity between the two groups. A significant effect, in favor of the intervention-group, was found for physical fitness, 3 months after finishing the fitness training ($p<0.01$). However, this significant effect on fitness was no longer present at follow-up. *Conclusion:* A behavioral change toward increased levels of daily physical activity was not achieved. Effects of the intervention on fitness were promising as significant effects were found 3 months after finishing training. Nevertheless, effects on fitness did not endure at follow-up.

Psychoperceptual responses following high-intensity functional electrical stimulation exercise training in spinal cord-injured individuals

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Abstract *Purpose:* This study investigated the effects of high-intensity interval training (HIIT) employing "hybrid"exercise (combined voluntary arm and functional electrical stimulation (FES)-leg cycling) in a virtual-reality environment on psychosocial perceptions in individuals with spinal cord injury (SCI). *Methods:* This was a parallel study in which twelve sedentary individuals with chronic SCI undertook 6 weeks of HIIT (80-90% HRpeak) using a hybrid exercise tricycle. Training sessions were either 32 minutes, thrice weekly or 48 minutes, twice weekly. The recumbent hybrid tricycle (BerkelBike®) was positioned on a stationary cycle trainer and connected to a flat panel LCD monitor enabling virtual reality (VR) cycling. Electrical stimulation was applied bilaterally to the quadriceps, hamstrings and glutei to evoke leg cycling. Voluntary arm-cranking was at a cadence selected by the subjects to achieve the target exercise intensity. Ratings of Perceived Exertion (BORG CR10 RPE), Exercise-induced Feeling Inventory (EIFI) and Profile of Mood States (POMS) were conducted at baseline and at the end of the final training session. *Results:* For both training regimes, exercise adherence was 100% and adherence to the exercise schedule was 88%. The mean RPE score changed from 6.0 ± 2.2 at baseline to 3.2 ± 1.8 ($p<0.05$) despite maintaining the exercise intensity. Feeling states improved at the end of training in all subscales of the EIFI, with a 44% increase in feeling of positive engagement, 76% increase in revitalization, 73% improvement in tranquility and 30% decrease in physical exhaustion. The depression, vigor, anger, tension and fatigue subscales of the POMS also changed favourably ($p<0.05$). *Conclusion:* Despite the stress and vigorous exercise intensity of HIIT, these previously sedentary SCI individuals reported positive post-exercise feeling states and mood following a short structured FES training programme.

Hot water immersion elevates interleukin-6 (IL-6) and IL-1RA in cervical spinal cord injury

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Abstract *Purpose:* Core temperature elevations can impact positively on immunity, potentially due to increases of catecholamines acting on immune cells' adrenergic receptors. The dysfunctional sympathetic nervous system in individuals with cervical spinal cord injury (CSCI) impairs adrenergic responses and may therefore contribute to depressed immunity and the occurrence of low grade systemic inflammation related disorders. However, some immune markers improve following exercise in CSCI, even though the positive effects are often blunted. Non-exercise induced body temperature manipulations have yet to be investigated in CSCI. *Methods:* Seven male participants with a motor complete CSCI and 8 male able-bodied controls were immersed for 60 min in water set at a temperature 2 ºC above the individuals' resting oesophageal temperature. Blood was collected pre, post, and every hour up to 4 h post immersion and analysed for interleukin-6 (IL-6) and IL-1ra. *Results*: Hot water immersion increased IL-6 by 130±107% in both groups ($P<0.001$), with a 73±37% higher average IL-6 concentration in CSCI ($P=0.04$). IL-1ra increased by 17±18% in both groups ($P=0.002$), with no difference between groups ($P=0.97$). DISCUSSION: The increases in IL-6 and IL-1ra in CSCI following hot water immersion are in contrast to earlier exercise interventions, where no cytokine elevations in this participant group were found. Possibly, the reduced active muscle mass in CSCI does not allow for sufficient core temperature elevations during exercise to increase these cytokines. Together with the lower catecholamine levels usually found in CSCI, this may explain the blunted exercise response on some aspects of immunity. This seems especially concerning as higher average levels of IL-6 support the indication of chronic low grade systemic inflammation in CSCI. *Conclusion:* Passive elevation of core temperature may help to improve the cytokine profile in CSCI, where the benefits of exercise on immune parameters can be blunted.

Oral presentations
Thursday, April 24, 2014

Keynote lecture 6: Prof. Dr. M. McNamee

Paralympism, species-specific limits, and the idea of impaired functioning

McNamee M

Citius, altius, fortius (faster, higher, stronger) is the well-known motto for the philosophy underpinning the Olympic movement known as Olympism. What kind of philosophy ought underpin the Paralympic movement has never, to my knowledge, been articulated. The context for my discussion will be International Paralympic Committee's declaration that safety, fairness, universality and human prowess are its guiding principles. The Paralympic Games bring together athletes with species atypical structure and functioning. While athletes with disabilities are often associated with the idea of impaired functioning, it is clear that some of these athletes function – through the aid of assistive technology and equipment, at far higher levels than so called "normal" human beings. In the presentation I (i) offer an account of Paralympism; (ii) raise questions as to whether the "natural athlete" ought properly to be seen as the paradigm of athletic excellence; and (iii) discuss the extent to which assistive technology may undermine Paralympic principles if not kept in check.

Oral presentations
Friday, April 25, 2014

Keynote lecture 7: Dr. C. Perret

Elite-adapted sports performance

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Abstract Elite-adapted sports performance has considerably improved in the last decades, but progress is levelling off. Further improvement may only be achieved through innovative training interventions or equipment adaptations. However, studies which include paralympic elite athletes are scarce. The present key note will focus on such interventions (e.g. respiratory muscle training, nutritional interventions, (pre)cooling methods as well as individual equipment adaptations), in order to improve elite adapted sports performance based on study results but also on personal single case experiences working with elite athletes with spinal cord injuries. It seems important to point out that personal (e.g. level and completeness of lesion) and sport-specific circumstances (e.g. hot environment, infrastructure, equipment regulations) have to be taken into account. As a result respiratory muscle endurance training, some supplementation strategies (e.g. caffeine, basic salts), cooling interventions as well as adaptations of the personal equipment display the potential to enhance elite adapted sports performance. However due to the limited number of elite athletes with a spinal cord injury available to participate in scientific studies, general conclusions are difficult at this stage and recommendations have to be still given mainly on an individual basis.

Keywords elite sports, Paralympic Games, exercise, peak performance, paraplegia, exercise physiology

Introduction

Elite-adapted sports performance has considerably improved in the last decades and winning or losing races at Paralympic Games is often a matter of a split second. Whereas the difference between first and third place at the Athens Paralympic Games 2004 (first time that handcycling was a Paralympic discipline) was 4.9%, it dropped below 0.6% in the same race category at the London Paralympic Games 2012. In other words, every single detail counts and such examples underline the necessity of optimizing training interventions and equipment for athletes in order to achieve top class performance. On the other hand, studies which include paralympic elite athletes to date are scarce, which make science-based general recommendations difficult.

Methods

The present key note will focus on different interventions in order to improve elite-adapted sports performance based on study results but also on personal single case experiences working with elite athletes with spinal cord injuries. These interventions include respiratory muscle training, nutritional interventions (e.g. supplementation), (pre)cooling methods as well as individual

equipment adaptations (e.g. aerodynamics, rear-wheel camber), taking into account the personal (e.g. level and completeness of lesion) and sport-specific (e.g. hot environment, infrastructure, equipment regulations) circumstances.

Results

Respiratory muscle endurance training (Mueller et al. 2008), some supplementation strategies (e.g. caffeine, basic salts) (Flueck et al. 2013), cooling interventions (Goosey-Tolfrey et al. 2008; Kocjan and Perret, 2008) as well as adaptations of the personal equipment (Mason et al. 2012; Perret and Strupler, 2012) display the potential to enhance elite-adapted sports performance, whereas other respiratory (Leicht et al. 2010; Perret and Mueller 2007) and nutritional interventions (Perret et al. 2006) failed to show performance-enhancing benefits.

Conclusion

In order to optimize exercise performance in elite-adapted sports nutritional and respiratory muscle training interventions as well as equipment adaptations seem to have some potential benefits. However, due to the limited number of elite athletes with a spinal cord injury available to participate in scientific studies, general conclusions are difficult at this stage and recommendations are still given mainly on an individual basis.

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Oral presentations
Friday, April 25, 2014

Session 9: Sports Analysis

The validity of a miniaturized data logger for accurately monitoring wheelchair rugby performance

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Abstract The purpose of this study was to determine the validity of a miniaturized data logger (MDL) for quantifying the demands of elite wheelchair rugby in comparison to a radio-frequency based indoor tracking system (ITS). Eleven international wheelchair rugby players were monitored by both devices during 4 wheelchair rugby matches. MDL data was averaged over both 1-second (MDL-1) and 5-second (MDL-5) intervals. The ITS and MDL provided data on the distances covered, mean and peak speeds reached. The time spent and distance covered in a number of speed zones relative to peak speed (Vmax) were also analyzed: <20%, 20-50%, 51-80%, 81-95%, >95%. No significant differences existed between devices for distance covered or mean speeds. However, large random errors in peak speed of 0.85 $m \cdot s^{-1}$ and 0.66 $m \cdot s^{-1}$ were revealed for MDL-1 and MDL-5 respectively. These errors in peak speed detection led to large random errors in the time spent and distance covered in relative speed zones, especially MDL-5. The current study revealed that although MDL provided a reasonable representation of distance and mean speed during wheelchair rugby, errors in the detection of peak speeds limit its use for monitoring and prescribing wheelchair rugby training programmes.

Keywords Wheelchair rugby, assistive technology, miniaturized data logger, radio frequency tracking

Introduction

A pre-requisite for sports scientists working within elite sports is being able to accurately quantify the demands of the sport and determine how these demands differ between athletes to facilitate the prescription of individualized training programmes. Global positioning systems (GPS) are heavily used in outdoor team sports since they offer a practical solution for acquiring performance data with an acceptable level of accuracy (Cummins et al., 2013). However alternative methods are required to assess the demands of indoor sports such as wheelchair rugby.

Radio-frequency based tracking systems are emerging, such as the Indoor Tracking System (ITS), which allows similar performance data to GPS to be collected indoors. The ITS has proven to be an accurate and reliable tool for the assessment of distance, mean and peak speeds during activities specific to wheelchair rugby. However, the ITS is a wired system which takes both time and expertise to set-up and calibrate, meaning it is not always a practical tool for use in an elite sport environment.

Alternatively, miniaturized data loggers (MDL) previously used to monitor activity profiles of daily life wheelchair users (Tolerico et al., 2007) have recently been introduced into wheelchair sports (Sindall et al., 2013). MDL offer a practical solution to data collection since they are lightweight devices equipped with long life batteries that attach easily to individual wheelchairs. Although, MDL accurately quantify distance and mean speed, poor reliability was demonstrated at speeds in excess of 2.5 $m \cdot s^{-1}$ when data was averaged at 5-second intervals (Sindall et al., 2013)]. The analysis intervals may explain the underestimations at high speeds associated with the MDL, which may be improved by employing a shorter analysis interval i.e. 1-second.

Therefore the aim of the current study was to determine the validity and reliability of the MDL when averaged over 1-second intervals and 5-second intervals compared to a radio-frequency based ITS for quantifying key performance variables specific to wheelchair rugby.

Methods

Eleven international wheelchair rugby players (age = 26 ± 6 years; body mass = 61.3 ± 10.5 kg) participated in the current study using their own customized rugby-specific wheelchairs. Each participant's wheelchair was equipped with two magnetic reed switch MDL near the axle of both main wheels. The MDL measures wheel rotation via three reed switches (120° intervals) and a magnet located at the bottom of a pendulum. As the wheel rotates a time stamp is recorded to the nearest 0.10 second each time a reed switch is activated. Using participant's wheel dimensions, distance and speed were calculated. Using a customized Matlab® programme, data were analyzed over 1-second (MDL-1) and 5-second (MDL-5) intervals.

The ITS requires six sensors to be positioned around the perimeter of the court, which communicate wirelessly with small, lightweight tags worn by the athletes. Sampling at 8 Hz, tag time and location can be monitored. Raw data was processed using a 3-pass sliding average filter with a window width proportional to tag frequency.

Data were collected during 4 simulated wheelchair rugby matches. Only full quarters were used for analysis. Total distance covered, mean and peak speeds were compared for each device. In addition, the time spent and distance covered in 5 speeds zones relative to peak speed (Vmax) of each device (<20%; 20-50%; 51-80%; 81-95%; >95%) were also analyzed.

Results

The current study revealed that there were no significant differences between devices for distance covered or mean speed (Table 1). However large random errors existed between ITS and MDL-1 (0.85 $m \cdot s^{-1}$) and MDL-5 (0.66 $m \cdot s^{-1}$; $p<0.0005$) for the detection of peak speed.

Table 1. The effect of device on performance parameters (mean±SD) assessed during full quarters of wheelchair rugby.

	ITS	MDL-1	MDL-5
Distance (m)	1403±168	1399±187	1401±186
Mean Speed ($m \cdot s^{-1}$)	1.26±0.10	1.26±0.13	1.26±0.14
Peak Speed ($m \cdot s^{-1}$)	3.91±0.32	3.85±0.45	2.75±0.29[a,b]

[a] significantly different to ITS; [b] significantly different to MDL-1 ($P<0.05$)

Errors in peak speed led to differences in the time spent in speed zones relative to peak speed, particularly in MDL-5, which underestimated the time spent in low speed zones and overestimated the time spent in high speed zones (Figure 1).

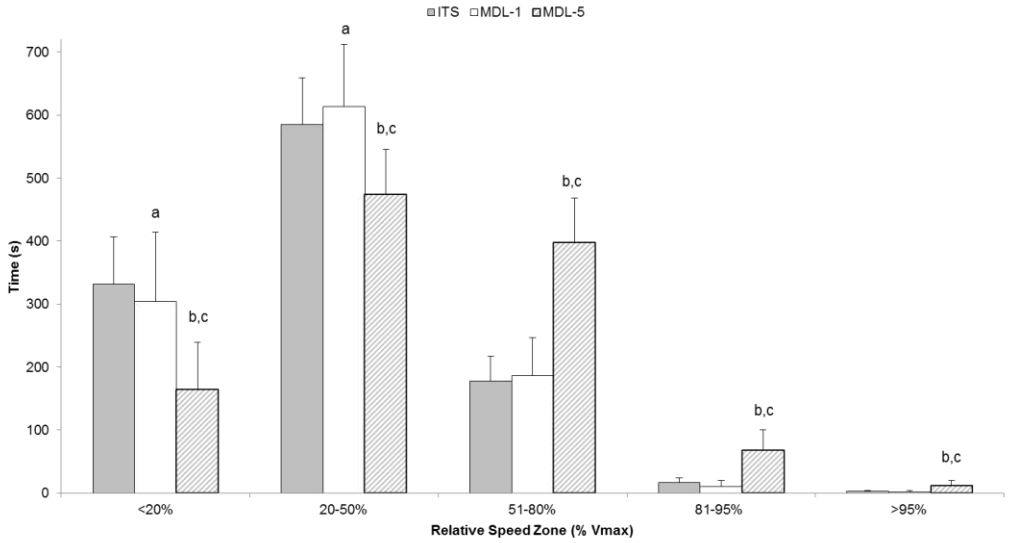

Figure 1. Influence of device on time spent in relative speed zones. Significant difference between: [a] ITS and MDL-1; [b] ITS and MDL-5, [c] MDL-1 and MDL-5 ($P<0.05$)

Conclusion

The MDL can be considered an appropriate tool for monitoring distance covered and mean speed during wheelchair rugby applications. However, it is currently not capable of accurately detecting peak speeds or the time spent and distance covered in specified speed zones. Therefore MDL are not recommended for use in the prescription or monitoring of athletes training programmes.

Acknowledgements

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Training for a handcycling mountain time trial: pilot study on the benefits for fitness

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Abstract The purpose of this study was to study the effects of a training period, prior to a handcycling mountain time trial (20 km, 1000 Hm+), on physical capacity and to monitor possible adverse effects due to training or the time trial.
47 Persons, predominantly with a spinal cord injury, were medically approved to participate in the mountain time trial. All were former patients participating in teams of eight Dutch rehabilitation centers. Laboratory peak graded exercise tests were performed in 6 out of 8 rehabilitation centers at the start (T1) and after 3 months semi-controlled training (T2) just prior to the time trial. Outcome measures were peak oxygen uptake (VO2peak) and peak power output (POpeak). Participants had to fill out a questionnaire about upper-extremity pain. Two weeks after the race the participants had to fill out a questionnaire about their recovery. VO2peak improved on average 12% from 2.11±0.60 L/min to 2.30±0.59 L/min (n=28, p=0.007) and POpeak improved on average 21% from 120±44 W to 141±48 W (n=31, p<0.001). Participants with relatively large improvements (> 15%) in POpeak were those with a significantly lower POpeak at T1 and who were less hampered by injuries. All participants finished the time trial. Two weeks after the time trial 34 out of 40 reported complete recovery; 4 still had to recover from minor to moderate upper-extremity (shoulder) complaints; 2 had serious chronic complaints, which were already present before the time trial. A large improvement in fitness is seen after the training period especially in those with a low physical capacity. A key factor for success in training for such an event is preventing overload (injuries) and, therefore, we advise an optimal ergonomic handcycling set-up, custom-made training protocols and to monitor the training with a diary.

Keywords handcycling, fitness, injuries

Introduction

In persons with a spinal cord injury (SCI) it is difficult, but very important, to exercise in order to stay fit and healthy (De Groot et al, 2013, Nash et al, 2005). For this reason the HandbikeBattle, a handcycling mountain time trial (20 km, 1000 Hm+), was organized to offer a challenge to train for. The aim of the current research project is to study the effects of a training period, prior to the HandbikeBattle, on physical capacity and to monitor possible adverse effects due to training or the event.

Methods

Participants

Forty seven competitors (age 38.5±11.3 yrs); 38 with a spinal cord injury, 2 with spina bifida, 2 with amputation and 5 with other diagnosis were medically approved for the event. All were former patients participating in teams of eight Dutch rehabilitation centers. Ten out of 47 subjects were familiar with the sport handcycling, the others were new to the rigid frame handcycle and started training with it especially for this event.

Protocol

Laboratory peak graded exercise tests were performed (figure 1) in 6 out of 8 rehabilitation centers at the start (T1) and after 3 months semi-controlled training (T2) just prior to the time trial. Outcome measures were peak oxygen uptake (VO2peak) and peak power output (POpeak). Two weeks after the race the participants had to fill out a questionnaire about their recovery.



Figure 1. Experimental set-up; arm cranking

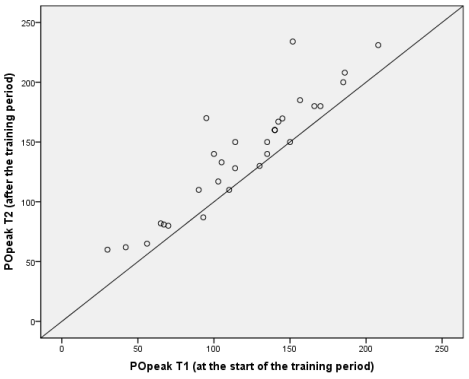

Figure 2. The individual improvement in POpeak

Statistical analysis

The change between the pre-and post training outcome measures was examined using a two-tailed Students' paired t-test ($p<0.05$).

Results

VO2peak improved on average 12% from 2.11± 0.60 L/min to 2.30±0.59 L/min (n=28, p=0.007). POpeak improved on average 21% from 120±44 W to 141±48 W (n=31, p<0.001). Figure 2 shows the individual improvement in POpeak of all participants. Participants with relatively large improvements (> 15%) in POpeak were those with a significantly lower POpeak at T1 and who were less hampered by injuries. All participants finished the time trial. Two weeks after the time trial 34 out of 40 reported complete recovery; 4 still had to recover from minor to moderate upper-

extremity (shoulder) complaints; 2 had serious chronic complaints, which were already present before the time trial.

Conclusion and discussion

This study involved many inexperienced but motivated handcyclists for whom this event was their first real serious sport training goal. A large improvement in fitness is seen after the training period especially in those with a relatively low physical capacity.
A key factor for success in training for such an event is preventing overload (injuries) and, therefore, we advise an optimal ergonomic handcycling set-up, custom-made training protocols and monitoring the training with a diary. Moreover, participants learned from each other and from the professionals about optimal preparation and training as well as how to overcome barriers that prevent them from training (Scelza, 2005).

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Prediction of peak oxygen uptake from differentiated ratings of perceived exertion in trained wheelchair sportspersons

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Abstract To assess the validity of predicting $\dot{V}O_{2peak}$ from differentiated ratings of perceived exertion (RPE) obtained during submaximal wheelchair propulsion. Specifically, the aim was to identify whether central RPE (RPE_C), peripheral RPE (RPE_P), overall RPE (RPE_O) or heart rate (HR) best predicted measured $\dot{V}O_{2peak}$ in three sub-groups of elite male wheelchair athletes (9 tetraplegics (TETRA); 9 paraplegics (PARA); 8 athletes without spinal cord injury (NON-SCI)). Each athlete performed an exercise test consisting of incremental stages, covering a range from 40% to 80% peak oxygen uptake (%$\dot{V}O_{2peak}$) followed by graded exercise to exhaustion ($\dot{V}O_{2peak}$ test). Oxygen uptake ($\dot{V}O_2$), heart rate (HR) and differentiated RPE were obtained for each stage. After confirmation that individual linear regression models provided the most appropriate fit to the data, the regression lines for the perceptual ranges 9 to 15 on the Borg 6 to 20 scale ratings were performed to predict $\dot{V}O_{2peak}$. There were no significant within group mean differences between measured $\dot{V}O_{2peak}$ (mean 1.50 ± 0.39; 2.74 ± 0.48; 3.75 ± 0.33 $L \cdot min^{-1}$ for TETRA, PARA and NON-SCI respectively) and predicted $\dot{V}O_{2peak}$ determined using HR or differentiated RPEs for any group (P>.05). However, the coefficients of variation (CV%) between measured and predicted $\dot{V}O_{2peak}$ using HR showed high variability for all groups (14.3, 15.9 and 9.7% respectively). The typical error ranged from 0.14 to 0.68 $L \cdot min^{-1}$ and the CV% between measured and predicted $\dot{V}O_{2peak}$ using differentiated RPE were ≤ 11.1% for TETRA, ≤ 7.5% for PARA and ≤ 20.2% for NON-SCI. Results suggest that differentiated RPE may be used cautiously for TETRA and PARA athletes when predicting $\dot{V}O_{2peak}$ across the perceptual range of 9 to 15. However, predicting $\dot{V}O_{2peak}$ is not recommended for the NON-SCI athletes due to the large CV%s (16.8, 20.2 and 18.0%; RPE_C, RPE_P and RPE_O respectively).

Keywords Exercise prescription, RPE, paraplegic, tetraplegic, aerobic capacity

Introduction

The use of ratings of perceived exertion (RPE) during dynamic exercise has been shown to be a valid indicator of the degree of physical effort (Borg 1970). RPE has been successfully used to predict maximal oxygen uptake ($\dot{V}O_{2max}$) during a variety of exercise modalities for both (AB) and paraplegic persons yet, no research has examined the efficacy of RPE for predicting peak oxygen uptake ($\dot{V}O_{2peak}$) during wheelchair propulsion exercise. Furthermore, typically 'overall' RPE which

is the integration of central and peripheral sensations of effort has been used. It is important to note that during wheelchair propulsion a smaller degree of muscle mass is activated when compared to whole body exercise. In fact, Lenton et al. (2008a; 2008b) found that during wheelchair propulsion 'peripheral' RPE dominated fatigue sensations and Paulson et al. (2013) suggested that 'peripheral' RPE enabled more precise self-regulation during moderate-intensity wheelchair propulsion.

Therefore, the aim of the present study was to assess the accuracy of predicting $\dot{V}O_{2peak}$ from differentiated RPE obtained during submaximal wheelchair propulsion in persons eligible to participate in wheelchair rugby and basketball. Specifically the aim was to identify whether central RPE (RPE_C), peripheral RPE (RPE_P), overall RPE (RPE_O) or HR best predicted $\dot{V}O_{2peak}$ in three sub-groups of wheelchair athletes (tetraplegic, TETRA); paraplegic (PARA) or athletes without spinal cord injury (NON-SCI).

Methods

Participants

Twenty-six elite male wheelchair athletes (9 C6-C7 tetraplegic (TETRA); 9 T6-L1 paraplegic (PARA) and 8 wheelchair athletes without spinal cord injury (NON-SCI)) volunteered to participate in the study. All exercise tests were performed in the participants' competition court sports wheelchair on a motorised treadmill (HP Cosmos, Traunstein, Germany).

To determine central RPE (RPE_C), participants were asked to rate their perceived exertion for the heart, lungs and breathing. To determine peripheral RPE (RPE_P), participants were asked to rate exertion only from the exercising muscle groups and joints. Overall RPE (RPE_O) was then determined as the combination of RPE_P and RPE_C. The RPE scale was visible to participants for the duration of the test and 'differentiated RPE' was prompted to the participant by the investigator during the last 15 s of each 4-min bout while the participant was still exercising. These RPE values across the range RPE 9 - 15 were obtained during the submaximal exercise test and used for the prediction purposes. Expired air was collected during the last minute of each exercise stage and analysed using the Douglas bag technique, HR was continually monitored.

Submaximal exercise test

Following a 5 min warm up at 1.2 $m \cdot s^{-1}$, participants performed ~6 submaximal constant-load 4-min exercise stages at ascending speeds at a fixed gradient of 1.0%. Tests were terminated when an RPE_O above 15.

Peak exercise test

Following 15-min passive recovery, a graded exercise test to exhaustion (GXT) was then performed at a constant speed according to the protocol described by Leicht et al. (2013). Participants then performed a verification test, designed as a test to exhaustion at the same constant speed but 0.3% and 0.1% higher than the maximal gradient achieved during the GXT for NON-SCI/PARA and TETRA respectively (Leicht et al., 2013). Expired air was collected for at least the final 3 consecutive min of the GXT and for 2 min during the verification test. The higher of the two $\dot{V}O_{2peak}$, HR_{peak} and blood lactate (BLa^-_{peak}) values obtained in the GXT and the verification test was taken as the peak value.

Statistics

Measured versus predicted $\dot{V}O_{2peak}$: Using individual participant linear regression, oxygen uptake ($\dot{V}O_2$) was regressed against the corresponding differentiated $RPE_{(C,P,O)}$ values of 9 to 15 and extrapolated to the theoretical maximal RPE (RPE 20) on the Borg scale to predict $\dot{V}O_{2peak}$. The same procedures were applied to when HR was used for the prediction.

Analysis of the validity of the predictions in $\dot{V}O_{2peak}$: The coefficient of variation (CVs) were computed for each predicted $\dot{V}O_2$ measurement across the RPE range (9 to 15) and unbiased typical error (TE) was also measured to quantify the relationship between predicted and measured $\dot{V}O_{2peak}$ values using the differentiated $RPE_{(C,P,O)}$ and HR values.

Results

Table 1. Measured $\dot{V}O_{2peak}$ values ($L \cdot min^{-1}$) from the graded exercise test for comparison against the predicted $\dot{V}O_{2peak}$ values from the differentiated RPE [9-15] and HR including the typical error (ratio coefficient of variation)

Parameter	TETRA	PARA	NON-SCI
$\dot{V}O_{2peak}$	1.50 ± 0.39	2.74 ± 0.48	3.75 ± 0.33
RPEc	1.47 ± 0.43; 0.15 (10.8%)	2.71 ± 0.63; 0.22 (7.5%)	3.68 ± 0.81; 0.54 (16.8%)
RPEp	1.52 ± 0.45; 0.16 (11.1%)	2.73 ± 0.57; 0.19 (6.5%)	3.92 ± 1.01; 0.68 (20.2%)
RPEo	1.50 ± 0.44; 0.14 (10.1%)	2.68 ± 0.57; 0.19 (6.5%)	3.80 ± 0.88; 0.59 (18.0%)
HR	1.54 ± 0.38; 0.18 (14.3%)	2.97 ± 0.70; 0.47 (15.9%)	3.82 ± 0.40; 0.35 (9.7%)

All values in $L \cdot min^{-1}$ with unbiased typical error and coefficient of variation (%)

Conclusion

Overall, these results suggest that differentiated RPE may be used cautiously for TETRA and PARA athletes when predicting $\dot{V}O_{2peak}$ across the RPE perceptual range of 9 to 15. It appears that central RPE (heart, lungs and breathing) and peripheral RPE (exercising muscle groups and joints) mediate overall RPE similarly during wheelchair propulsion. However, predicting $\dot{V}O_{2peak}$ using these methods is not recommended for the NON-SCI athletes due to the large CV%s (16.8, 20.2 and 18.0%; RPE_C, RPE_P and RPE_O respectively). This may be explained by the greater variability of the disabilities noted within this group. Future work is warranted to examine the impact of trained status, exercise modality, constant load vs. continuous and intermittent exercise protocols in this cohort of wheelchair games players.

Acknowledgements

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Acute changes in brain-derived neurotrophic factor concentrations during wheelchair rugby training

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Abstract The purpose of this study was to investigate acute changes in serum brain-derived neurotrophic factor (BDNF) concentrations during a typical training session of wheelchair rugby athletes with a tetraplegical spinal cord injury. Eleven male athletes completed a 90 min training session including a warm-up period, a main part including a game and finally a cool-down. Venous blood samples were taken at rest, after the warm-up period and following the main training part. Serum was pipetted after 30 minutes of sample resting and a following centrifugation. BDNF concentration was measured using an enzyme immunoassay ELISA kit. During the warm-up period the athletes did continuous pushing of about 10 minutes, followed by eight 20 m submaximal increasing sprints and agility drills. A stretching program of the upper extremities completed the warm-up. The main training part contained ball handling, passing drills, scrimmage activity and tactical practice, which lasted 45 minutes. At the end of the training session the athletes did moderate continuous pushing as a short cool-down. At rest BDNF concentrations were 33.23 ± 21.58 ng/ml, after warm-up 31.89 ± 18.93 ng/ml and after the training session 29.9 ± 10.98 ng/ml. No significant differences were obtained. In comparison to healthy subjects the measured concentrations at rest and after activity were significantly higher. In conclusion there is no positive influence of a typical training session of wheelchair rugby athletes on serum BDNF concentration.

Keywords spinal cord injury, BDNF, wheelchair rugby, neurophysiology

Introduction

The potential of regular or single bouts of physical activity, such as aerobic endurance exercise or strength training, is associated with manifold positive effects for able-bodied and spinal cord injured individuals. Beside an improved cardiorespiratory health and muscular capacity, mental and neuronal health is increased as well. Here neurotrophic factors such as brain-derived neurotrophic factor (BDNF) play a vital role in terms of neurogenesis, neuroplasticity nerve protection (Knaepen, 2010). Rojas Vega et al. (2008) demonstrated increased BDNF values after moderate hand cycling activities in paraplegic athletes. The main objectives of this study were 1) to evaluate the influence of exercise (wheelchair rugby training) on serum BDNF concentrations in tetraplegic athletes and 2) to compare these results with paraplegic athletes and able-bodied subjects.

Methods

Subjects

Eleven male elite wheelchair rugby athletes (age: 31.73 ± 5.92 years; height: 185 ± 0.06 cm; weight: 74.55 ± 7.83 kg) with a tetraplegical spinal cord injury (SCI; spinal lesion level C5-C7; ASIA A and B according to the American Spinal Injury Association) were recruited for the study. They were active in wheelchair rugby since 5.73 ± 4.13 years and all members either of the German or Polish national team.

Training session

The training session included a warm-up period, a main part and finally a cool-down. During the warm-up period the athletes did continuous pushing about 10 minutes, followed by eight 20 m submaximal increasing sprints and agility drills. Stretching of the upper extremities completed the warm-up. The main training part contained ball handling, passing drills, scrimmage activity and tactical practice, which lasted 45 minutes. At the end of the training session the athletes did moderate continuous pushing as a short cool-down. Overall the training session lasted 90 minutes.

At rest, before and immediately after the training, heart rate was measured. In addition average and maximum heart rate during the warm-up and during the first and second half of the training session were recorded. Capillary blood samples for lactate determination were taken from earlobe at the same time as the heart rate measurements.

BDNF measurement

Venous blood samples were taken at rest, after the warm-up period and after the first half of the main training part. Serum was pipetted after 30 minutes of sample resting and a following centrifugation at 4000 rpm for 10 minutes at 4°C. The samples were stored in Eppendorf tubes firstly 4 hours at -18°C in a mobile freezer and after that at -40°C. Using enzyme immunoassay ELISA kits (R&D Systems, Minneapolis, USA).

Statistics

All data are shown as mean ± standard deviation. Analysis of variance was conducted by using ANOVA for repeated measurement. Significant results were evaluated with the Bonferroni post-hoc test. The level of significance for all analyses was set at $p<0.05$.

Results

Training session

At rest the lactate concentration was 1.07 ± 0.30 mmol/l, after the warm-up 3.38 ± 1.86 mmol/l and after the training session 2.34 ± 0.92 mmol/l. According to this data mean heart rate was 72.82 ± 6.98, 99.30 ± 19.00 and 104.92 ± 12.69 bpm. Maximal heart rate during warm-up was 129.20 ± 16.25 and mean was 103.57 ± 16.25 bpm. During training the athletes reached a maximal heart rate of 125.20 ± 13.59 and mean of 103.00 ± 13.06 bpm.

BDNF concentration

In rest BDNF concentrations were 33.23 ± 21.58 ng/ml, after warm up 31.89 ± 18.93 ng/ml and after the training session 29.9 ± 10.98 ng/ml. Here, no significant differences were obtained.

Conclusion

Under the current conditions there is no positive influence of a typical wheelchair rugby training session for athletes with a tetraplegical SCI on serum BDNF concentrations. Effects of physical activity in terms of increased BDNF levels for able-bodied subjects and for paraplegic athletes depend on exercise intensity and duration (Rojas Vega et al., 2008; Zoladz & Pilc, 2010). In comparison to able-bodied subjects the current BDNF concentrations at rest were about 5-8-fold higher. According to these results further studies should examine the possible increase of BDNF levels in tetraplegic spinal cord injured subjects at different types, durations and intensities of exercise.

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Oral presentations
Friday, April 25, 2014

Session 10: Exercise Physiology

Effects of wearing a cooling vest during exercise on thermoregulation of spinal cord injured individuals

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Abstract Individuals with a spinal cord injury (SCI) have a disturbed thermoregulation, which is partly due to the loss of sympathetic regulation below the lesion. Therefore, SCI individuals show a larger increase in core body temperature (Tc) skin temperature (Tskin) above the lesion compared to able-bodied controls during exercise. Cooling strategies may be beneficial to reduce the thermophysiological strain for SCI individuals. Therefore, the aim of this study was to examine the effects of a cooling vest on thermoregulatory responses of SCI individuals during sub-maximal exercise in the heat. Seven men (26-54 years) with a low lesion (T5<) were included to participate in this randomized cross-over study. Subjects performed a maximal arm-crank exercise test, followed by two 45 minute sub-maximal arm-cranking exercise tests (with and without cooling vest, in randomized order) at 50% of maximal power output and an ambient temperature of 25°C. During sub maximal exercise, we continuously measured Tc (ingestible pill + telemetry), Tskin (skin thermistors at 10 places, divided into upper and lower body skin temperature), and heart rate (Polar chest band). Moreover, ratings of perceived exertion (RPE) and thermal comfort were asked every 3 minutes. Exercise resulted in an increased Tc, upper body Tskin, heart rate, RPE and thermal comfort (all $p \leq 0.01$). The cooling vest effectively decreased upper body Tskin temperature ($P<0.01$), increased the core-to-skin temperature gradient ($P<0.01$) and resulted in a lower thermal comfort score ($P=0.02$). However, the cooling vest did not impact on Tc, heart rate, lower limb Tskin and RPE responses during exercise (all $P>0.05$). Therefore, wearing a cooling vest during arm-crank exercise in SCI individuals effectively lowered upper body Tskin, and improved thermal comfort score during exercise. Nonetheless, we found no evidence that the cooling vest reduced thermophysiological responses under temperate ambient conditions.

Keywords Core body temperature, skin temperature, paraplegic, percooling

Introduction

Individuals with a spinal cord injury (SCI) have a disturbed thermoregulation, at least partly due to the loss of sympathetic regulation below the level of the lesion. The disruption of the spinal cord affects the ability to vasoconstrict and vasodilate the peripheral vasculature below the level of the lesion, but also impairs sweating capacity (Petrofsky, 1992). This underlies the clinical observation that SCI individuals have an increased risk of heat exhaustion and thermal injury (Price, Campbell, 1997). Cooling during exercise (percooling) can prevent excessive heat storage during exercise and can attenuate the increase in core body temperature (Tc). Therefore,

percooling may be beneficial to prevent against heat-related problems (Hagobian, Jacobs et al., 2004). Previous studies that examined cooling strategies during exercise in SCI patients reported conflicting results (Webborn, Price, 2005; Armstrong, Maresh et al., 1995), potentially related to the transient nature and/or mild impact of the cooling strategies. Recently, a new cooling vest is developed, which is claimed to have a prolonged cooling impact during exercise. Therefore, the aim of the study is to examine the effect of a cooling vest on the change in core and skin temperature in SCI individuals during submaximal arm-crank exercise.

Methods

Participants & Experimental design

A total of 7 male participants with a thoracic spinal cord injury (lesion T5 or lower) were included in this study. All participants underwent a medical examination and reported three times to the laboratory. During the first day, participants performed a continuous incremental arm-cranking exercise until volitional fatigue to determine maximal power output. On day 2 and 3, participants underwent a continuous 45 minutes arm cranking exercise in 25°C at 50% of their individual maximal power output. In randomized order, participants wore a cooling vest during one of these days. Efforts were made to keep other conditions similar during both testing days.

Outcome measures

The following outcome variables were assessed during exercise:

- Core body temperature (Tc) was measured with a portable telemetric CorTemp temperature pill, which measure the Tc every 20 seconds. This is a valid and reproducible method to record (changes in) Tc (Byrne, Lim. 2007).
- Skin temperature (Tskin) was measured continuously with wireless temperature recorders (iButtons). A total of 8 iButtons were attached all around the body. Mean Tskin was calculated as well as upper (Tskin UB, 6 recorders) and lower (Tskin LB, 2 recorders) part of the body (which corresponded with above and below the level of the lesion).
- Heart rate (HR) was measured continuously using a ECG chest band system.
- Core-to-skin temperature gradient was calculated using the Tc and Tskin data.
- Thermal sensation score (ranging from +3 to -3, in steps of 1) and rate of perceived exertion (RPE, ranging from 6 to 20, in steps of 1) score were asked every 3 minutes during the exercise bout to assess the participants' subjective feeling regarding the temperature and exercise intensity.

Statistical analysis

A one-way ANOVA was used to assess differences in exercise characteristics between the cooling and control condition. Changes over time in Tc, Hr, mean Tskin, Tskin UB, Tskin LB, thermal sensation and RPE between cooling and control condition were assessed using a two-way repeated measures ANOVA.

Results

In both conditions, Tc and HR significantly increased during exercise ($p<0.01$), whilst this increase did not differ between groups ($p=0.72$ and $p=0.29$ respectively). The maximum Tc did not differ between the control and cooling condition ($p=0.70$). Furthermore, a lower mean Tskin and Tskin UB was demonstrated for the cooling condition compared to the control condition

(p=0.02 and p=0.01 respectively), whilst the Tskin LB was comparable between conditions (p=0.18).

Core-to-skin temperature gradient was significantly higher in the cooling condition (p<0.01), whilst this gradient did not change over time in both conditions (p=0.44). Finally, mean thermal sensation score during exercise was lower in the cooling condition (p=0.02), whilst the RPE was comparable between groups (p=0.11).

Table 1. Exercise characteristics for both cooling and control condition. Data were presented as mean ± standard deviation. ***** represents significance difference at p<0.05.

Outcome variable	**Cooling**	**Control**	**Outcome variable**	**Cooling**	**Control**
Maximum Tc (°C)	38.01±0.29	37.96±0.46	Mean Tskin (°C)*****	32.43±0.44	33.20±0.57
Δ Tc (°C)	0.85±0.28	0.79±0.35	Tskin UB (°C)*****	34.49±0.47	34.97±0.46
Thermal sensation *****	1.3±0.7	1.7±0.7	Tskin LB (°C)	32.33±1.10	32.63±0.92
RPE	3.4±0.7	3.8±0.7	Core-to-skin temperature gradient (°C)*****	3.67±0.83	2.73±0.58

Conclusion

In conclusion, wearing a cooling vest during submaximal arm-crank exercise in SCI subjects with a complete thoracic injury was effective in lowering the mean Tskin, and in particular the Tskin in the upper limb (i.e. where the cooling vest was applied to). In addition, the cooling condition induced a larger core-to-skin temperature gradient, which indicated that the cooling vest facilitated the loss of heat during arm-crank exercise. Furthermore, the cooling vest had a positive effect on thermal sensation, resulting in a lower subjective sensation of heat. Despite these effects of the cooling vest, wearing a cooling vest did not impact on maximum Tc, ΔTc, HR, Tskin LB and RPE.

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Effects of caffeine supplementation on sprint, 4-min push and cognitive performance in wheelchair sportsmen

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Abstract The purpose of this study was to determine the effects of caffeine supplementation on 20 m sprint (SPR), 4-min push (PUSH) and cognitive performance in wheelchair sportsmen. A placebo-controlled, randomised study design was employed. Twelve wheelchair rugby players (mean±SD: age 30.0±7.7 y, body mass 69.6±15.3 kg, training hours 11.1±3.5 h/wk) completed two trials, separated by a maximum of 14 d, 45 min after ingestion of 4 mg/kg caffeine (CAF) or glucose (PLA). The protocol consisted of a 20-min warm-up, 3 sets of 3xSPR and 4 sets of PUSH. Each set was separated by 4 min rest. Cognitive performance, thermal, feeling and arousal scores were measured pre-capsule, pre-exercise and post-exercise. Rating of perceived exertion (RPE) was collected after each SPR and PUSH.There was a significant effect of CAF on mean SPR performance ($p=0.049$) compared to PLA (mean 7.18±1.14 s and 7.26±1.19 s, respectively). There was no significant effect of treatment on PUSH performance ($p=0.11$) however, significantly more distance was covered in PUSH1 during CAF ($p=0.047$) compared to PLA (mean 677±107.4 m and 653±118.4 m, respectively). Mean total PUSH distance was significantly less during PLA ($p=0.047$) for spinal cord injured (SCI) players compared to non-SCI (2449±308.7 m and 2893±370.1 m, respectively) but was similar during CAF ($p=0.073$) (2507±367.9 m and 2938±369.2 m, respectively). A significant improvement in Stroop scores (no interference) was seen post-exercise independent of trial, compared to previous time-points ($p<0.05$). There was a significant effect of time for the thermal, arousal and RPE scales ($p<0.05$) however, there was no difference between trials. There was a significant increase in feeling scores across time during CAF ($p=0.017$) but not PLA. In conclusion, caffeine improved aspects of SPR and PUSH performance in wheelchair sportsmen. CAF did not influence thermal, arousal or RPE but did improve feeling scores.

Keywords cognitive function, Stroop, RPE, feeling, endurance

Introduction

A large body of evidence from able-bodied studies has accumulated over recent years indicating that moderate doses of caffeine (3-6 $mg \cdot kg^{-1}$) are likely to have performance benefits across a range of sports (Burke 2008). The majority of these studies employed exercise protocols in which performance is highly dependent on the leg muscles (running/cycling). The physiological responses to such modes of exercise differ to those produced during upper-body exercise and hence the findings cannot be directly transferred. However, the current view is that caffeine acts antagonistically on adenosine receptors and therefore blocks its actions (reduced arousal,

wakefulness and motor activity) causing the work-enhancing and fatigue-reducing effects repeatedly seen in the literature. Hence, if caffeine acts via the central nervous system then an ergogenic benefit should potentially also be seen during upper-body exercise. Very few studies have investigated the use of caffeine during upper-body exercise and further research is warranted. The study aim was therefore to determine the effects of caffeine supplementation on 20 m sprint (SPR) and 4-min maximal push (PUSH) performance, and to assess the cognitive function and subjective feelings of wheelchair sportsmen.

Methods

Twelve male wheelchair rugby players (mean±SD): age 30.0±7.7 y, body mass 69.6±15.3 kg, and training hours 11.1±3.5 h/wk) volunteered. Participants performed two main experimental trials separated by at least 7 d but no more than 14 d. Participants were randomly assigned to receive either placebo (PLA) or caffeine (CAF) (4 mg·kg^{-1} caffeine, Sigma-Aldrich, Dorset).

The performance tests included 1) SPR (1 set=3 SPR) times were recorded using wireless timing gates (Brower Timing System, Utah, USA), 2) PUSH around a 72 m course, and 3) cognitive function was assessed via a version of the Stroop test. Participants' rating of perceived exertion (RPE), feeling, arousal and thermal sensation scores were also recorded. Participants were asked to refrain from caffeine consumption in the 48 h, and from exercise in the 24 h preceding each trial. Participants were asked to prepare as they would normally for a training session and to replicate this prior to both trials. See Figure 1 for a schematic of the experimental trial procedures.

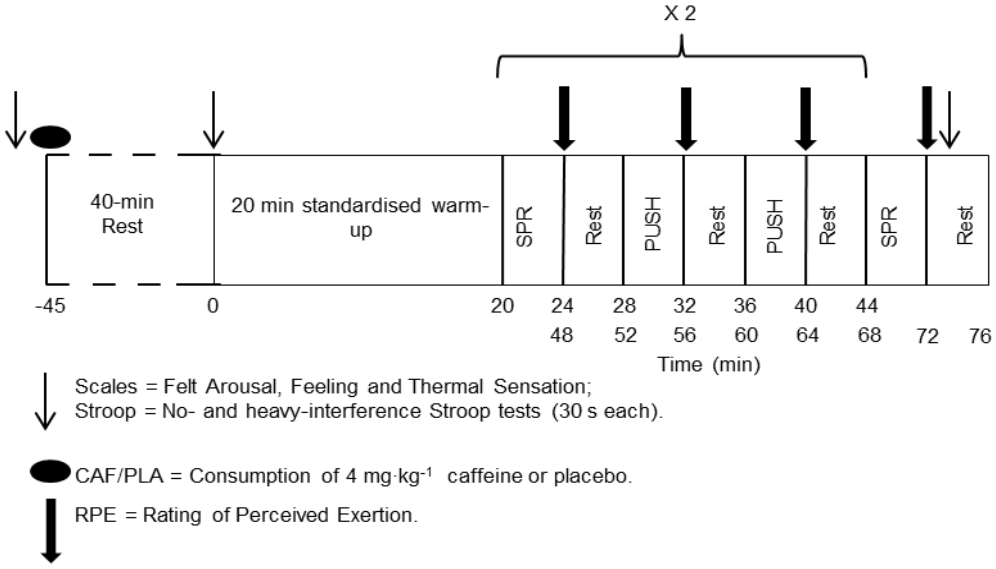

Figure 1. Schematic of the experimental trial protocol.

Differences in performance tests were evaluated using two-way repeated measures ANOVAs. Non-parametric Friedman and Wilcoxon signed-rank tests were used to analyse differences in feeling, Felt arousal, RPE and thermal sensation scores. Significance was set a priori at $p \leq 0.05$.

Results

There was a significant improvement in mean SPR (p=0.049) during CAF compared to PLA (mean 7.18±1.14 s and 7.26±1.19 s, respectively). Post-hoc analysis revealed faster mean SPR times during CAF for the first and second sets of SPR compared to PLA (p=0.046 and 0.010, respectively). Nine participants recorded better SPR times during CAF than PLA (Figure 2).

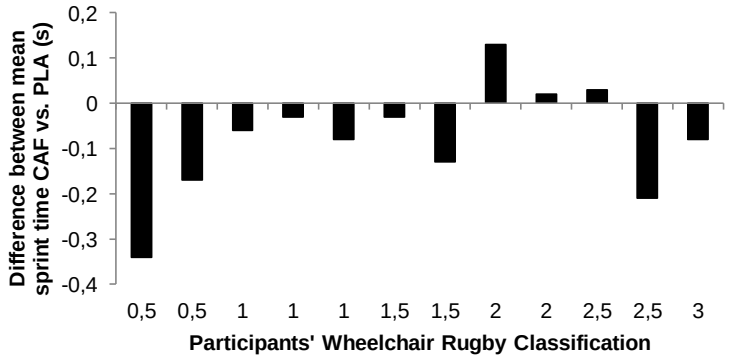

Figure 2. Individual participants' difference between mean sprint time during CAF compared to PLA.

There was no significant main effect of trial (p=0.111) or time (p=0.060) for PUSH distance. However, participants covered significantly more distance during PUSH1 during CAF compared to PLA (p=0.047). Overall, seven participants covered a greater total PUSH distance during CAF than PLA. Total PUSH distance was significantly less (p=0.047) during PLA for participants with a SCI compared to non-SCI (2449±308.7 m and 2893±370.1 m, respectively) but was not significantly different (p=0.073) during CAF (p=0.073) (2507±367.9 m and 2938±369.2 m, respectively). There was no influence of disability on any other outcome measure (p>0.05).
There was a significant effect of time on NI Stroop test scores (p=0.008) seen as an improvement post-exercise independent of trial, compared to previous time-points (p<0.05). There was no significant effect of trial on NI or HI Stroop test scores or errors (p>0.05). There was a significant increase in feeling scores across time during CAF (p=0.017) but not PLA (p=0.197), and there was no difference between trials at any time-point (p>0.05). There was a significant main effect of time (p<0.05) but not trial (p>0.05) for the thermal, arousal and RPE scales. Five participants reported side-effects during CAF; increased spasticity, feelings of sickness and feeling hyper.

Conclusion

Caffeine may have the potential to improve aspects of wheelchair sport performance however, responses are individual. Wheelchair sportsmen wishing to use caffeine to improve performance should trial the use of a moderate dose during training to ensure they experience no side-effects.

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Autonomic control and elite paracycling performance in spinal cord injury

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Abstract Spinal cord injury (SCI) induces alterations in autonomic control that may attenuate the cardiovascular response to exercise and limit endurance performance. *Purpose:* We aimed to determine the relationship between level of injury, autonomic completeness of injury, exercise hemodynamics and endurance performance. *Methods:* Twenty-five elite male Paracycling athletes were grouped by injury level (C3-C8, n=12; T1-T8, n=13) and were assessed for neurological completeness of injury (standard neurological evaluation), autonomic completeness of injury (sympathetic skin responses), and time to complete a 17.3 km World Championship time-trial field test. A subset of these athletes were also fitted with heart rate (HR) monitors and their cycles were fitted with a global positioning systems device (n=15) to assess HR and speed during the time-trial, respectively. *Results*: Cervical SCI exhibited a slower time-trial time ($p<0.001$) and a lower maximal, average and minimum speed vs. thoracic SCI ($p<0.001$). Maximum HR was not different in cervical vs. thoracic SCI ($p=0.082$), but average HR was substantially lower in cervical SCI ($p=0.005$). Further stratification of cervical and thoracic SCI athletes into autonomic complete/incomplete revealed that the four athletes with cervical autonomic incomplete SCI finished in the top four race positions out of all cervical athletes; hence, time-trial time, maximal speed and average speed were faster in cervical autonomic incomplete vs. cervical autonomic complete SCI (all $p<0.035$). Maximum and average HR also tended to be higher (~10-15%) in cervical autonomic incomplete vs. cervical autonomic complete SCI. There were no differences in any exercise indices between autonomic incomplete vs. complete thoracic SCI. *Discussion:* We demonstrate for the first time that autonomic completeness of injury and the consequent ability of the cardiovascular system to respond to exercise is a critical determinant of endurance performance in cervical SCI.

Autonomic cardiovascular control in paralympic athletes with spinal cord injury

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Abstract *Purpose*: To assess the effect of lesion level, along with motor, sensory, and autonomic completeness of injury, on cardiovascular control in Paralympic athletes with spinal cord injury (SCI). *Methods:* 70 Paralympic athletes (55 Male, age 37.4 ± 8.2 y) with chronic SCI (C2-L2) underwent 3 experimental assessments. During assessment 1, neurological examination was completed according to the American Spinal Injury Association Impairment Scale (AIS). During assessment 2, autonomic completeness of injury was evaluated via sympathetic skin responses (SSRs) to median nerve stimulation, whereby those with a score 0-1/5 were considered autonomic complete. During assessment 3, cardiovascular control was examined via the beat-by-beat blood pressure response to orthostatic challenge. *Results:* Athletes with cervical SCI exhibited the lowest seated blood pressure and the most severe orthostatic hypotension (OH; $p<0.009$). There were no differences in cardiovascular function between athletes with different AIS grades ($p>0.12$). Conversely, those with autonomic complete injuries exhibited the lowest seated blood pressure and the most severe OH ($p<0.005$). Further stratification of level of injury by autonomic completeness of injury revealed that autonomic complete cervical SCI ($n=21$) had a lower supine blood pressure ($p=0.044$), seated blood pressure ($p=0.001$) and the most severe OH ($p=0.003$) compared to autonomic incomplete cervical SCI ($n=7$). *Conclusion:* We demonstrate for the first time that individuals with cervical SCI who exhibit an autonomic complete injury exhibit a greater degree of cardiovascular disturbances compared to lesion-level matched autonomic incomplete SCI. We advocate that the use of autonomic testing could be useful addition for clinical and sporting classification of individuals with SCI.

Oral presentations
Friday, April 25, 2014

Keynote lecture 8: Dr. N. Webborn

Sports Injuries in Wheelchair Sports and Athletes

Webborn N

Historically, and for convenience, we have grouped together in a descriptive term athletes that use a wheelchair in some form or other as 'wheelchair athletes'. There are athletes that use a wheelchair for daily living, but not for their chosen sport as in swimming or powerlifting, and also amputees that use a chair for sport but not in daily life. Consequently our understanding of injury incidence and aetiology has been somewhat confused by early studies that combined sports and impairment types. They gave an initial insight into injury patterns but sports have evolved significantly in the last decade with changes in equipment and training intensities making their conclusions less accurate. Sports wheelchair technology has also evolved over the last twenty years. In the early days of sport for people with disabilities the athletes would use the same wheelchair provided by the health care provider for daily living and sport. The chair designs became specific for the sport and hence design factors such as the seating position, camber angle of the wheels, chair length and height became not only specific to the sport but also to the individual athlete and their particular impairment. As a consequence the biomechanics of pushing in each sport is different and the tissues put under load vary. If we aggregate data on injury surveillance purely by wheelchair users in sports we can confuse our understanding of injury type and causation.

The IPC's injury and illness surveys commenced in the Winter Games of 2002 and have run at consecutive Winter Games since then and have influenced injury prevention through changes in equipment and technical regulations. London 2012 saw the first injury survey at a summer Paralympics and the results will be discussed along with the implications for future studies in the presentation. To have effective injury prevention we have to discard this generic approach and develop sport and disability specific information in longitudinal studies. Longitudinal data is not only important to understand how injury impacts on sport participation and performance but also to understand the longer term consequences of participation in sport which have yet to be addressed in Paralympic sport. It is not yet clear whether sport participation will have beneficial or detrimental on future health and this is likely to be sport and impairment specific.

Oral presentations
Friday, April 25, 2014

Session 11: Wheelchair Sports

The relationship of the repeated sprint test and related field tests' outcomes in wheelchair basketball players

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Abstract The purpose was to examine the relationship between indices of the repeated sprint test (RST) and of specific aerobic and anaerobic field tests in wheelchair basketball players. Twelve wheelchair basketball players from one team participated. All tests were performed with the individual's basketball wheelchair on an outdoor elliptical cement course during the evening hours at a comfortable temperature, after a 15-min warm-up period,in two sessions. RSTs were performed using an eight-sprint repetition model of 20 m distances with 30-sec recovery. The best sprint times (RSTbest), mean sprint times (RSmean) and percent sprint decrement (RST%dec) were calculated for the RST. Lactic acid, heart rate (HR) and rating of perceived exertion (RPE) measurements were taken at the end of the RST. Aerobic test (6min) performance was measured using the maximum distance gained during 6 min on the outdoor course. HR and RPE were also measured at the end of the distance test. Anaerobic continuous test (ANC) performance was measured using a timed 160 m continuous sprint, with break-downs for every 20 m section. Total time (ANCtot), mean time (ANCmean), fastest 20 m section time (ANCbest), and the decrement from fastest to slowest section times (ANC%dec) were calculated for the ANC and RST. Pearson correlations between test indices were analyzed. Significant high correlations were obtained between RSTbest and ANCbest (r=0.94), RSmean and ANmean (r=0.95), RSbest and AT (r=0.88). Low non-significant negative correlation were determined between the RST%dec and the ANC%dec (r=-0.24), or RST%dec and 6min (r=-0.05). Our findings express a predictive validity of RSTbest and RSTmean and the substantial contribution of anaerobic power indices to the RST results compared to the aerobic input.

Keywords Wheelchair basketball, Field tests, Measurement

Introduction

The importance of intense intermittent exercise in ball games such as soccer or basketball is well established (Bangsbo, 1994). The repeated sprint test (RST) was developed in the past three decades as a useful functional field test for measuring intermittent exercise relating to both aerobic and anaerobic components. The term repeated sprint ability was introduced by Dawson and associates (e.g., Dawson et al., 1991; Dawson et al.,1993) as the ability to regularly reproduce maximal sprint efforts. Initial users of RST have used 20 m ×7 sprints every 30 s., or other combinations of tests covering 20-40 m sprints, with 6-18 repetitions and recovery durations of 15-30 s. Among the RST performance indices are % of performance deceleration significantly correlated with VO2 max (r=-.60) and fastest sprint time, and total sprint time significantly

correlated (r range = .42-.47) with mean power during the Wingate Anaerobic Test (WAnT), in soccer players (Meckel et al. 2009). In wheelchair sports RST has been used for informing about respiratory function, using a 15 repetitions X 20 m protocol with as little rest as possible between sprints (Goosey-Tolfrey et al., 2010). The purpose of the current study was to examine the relationship between indices of the RST and of specific aerobic and anaerobic field tests in wheelchair basketball players. We hypothesize that (a) performance decrement in RST should correlate with a specific aerobic outcome (6min distance); (b) the fastest mean time in RST should correlate with peak performance of the specific anaerobic continuous test (ANC); and (c) total (mean) performance in RST should correlate with mean performance in the specific ANC.

Methods

Participants

Twelve male wheelchair basketball players from one team (Mean age = 28; SD=10), competing in the first league in Israel, volunteered to participate in this study. Their basketball classifications ranged between 1 and 4.5 points.

Tests' description and procedure

Measurements were performed a few weeks prior to the game season; the athletes were training three times per week at that time. All tests were performed with the individual participant's basketball wheelchair on an outdoor elliptical cement course during the evening hours at a comfortable temperature (22-24 degrees Celsius). Tests were conducted after a 15-min warm-up period in two sessions. RSTs were performed using an eight-sprint repetition model of 20 m distances with a 30-sec recovery. Each sprint was timed using photoelectric gates. The best sprint times (RSTbest) and mean sprint times (RSTmean), and the percent sprint decrement (RST%dec), were calculated. Lactic acid, heart rate (HR) and rating of perceived exertion (RPE) measurements were taken at the end of the RST. Aerobic test (AT) performance was measured using the maximum distance wheeled during 6 min on the outdoor course. HR and RPE were also measured at the end of the distance test. Anaerobic continuous test (ANC) performance was measured using a manually-timed 160 m continuous sprint, with break-downs for every 20 m sections. Total time (ANCtot), mean time (ANCmean), fastest 20 m section time (ANCbest), and the decrement from fastest to slowest section times (ANC%dec) were calculated. Rating of perceived exertion (RPE) was taken on a scale of 1 to 10 after each test.

Statistical analysis

Pearson correlations between indices of the different tests were analyzed. In addition, correlations were calculated between test results and background variables (age, basketball experience, and classification). T-tests were used to compare between similar indices of the RST and the ANC.

Results

Very high correlations were obtained between two indices of the RST and the ANC, with r=0.94 between RSTbest and ANCbest, r=0.955 between RSTmean and ANCmean, but a low negative correlation (r=-0.24) between the RST%dec and the ANC%dec. Similarly, high correlations were found between best and mean indices of RST and the 6min distance (r=0.88 in both), and no correlation between RST%dec and 6min distance (r=-0.05). Correlations between background variables and test outcomes indicated a medium relationship (r= .61; p<.05) between Classification and 6min. Experience in wheelchair basketball correlated with all outcome indices

except for %Dec (r =.69 for 6min distance; *p*<.05; r= -.65; p<.05 for RSTmean and RSTbest and-.60 to.-.77; *p*<.05 to.01 for ANCmean and ANCbest, respectively). Age correlated with fatigue in the anaerobic continuous test (r=-.77; *p*<.01). Table 1 presents the mean data of the 12 participants in similar indices of the RST and ANC.

Table 1. Comparison between Similar Indices in the ANC and RST

Indices	ANC	RST
RPE*	1.37±8.42	2.40±4
MST (Sec) *	0.62±4.84	0.57±5.28
PST (Sec) *	0.525±4.12	0.56±5.16
TOTAL Time (Sec)	5.02±38.75	0.566±42.28
Dec% (Fatigue) *	29.8±6	2.4±1.0

Conclusion and discussion

Based on the very strong relationships between the RST and the indices of the ANC and 6min, it may be suggested that this thr RST could be a useful field test for measuring both aerobic and anaerobic performance variables. The strong relationships between background variables and the RST may contribute to this suggestion.

The very small decrease in performance over repeated sprints indicates that the specific RST protocol used may have not been strenuous enough. Therefore, future protocols should be designed, considering (a) more sprints (e.g., 12), longer distances (e.g., 40 m) and shorter recovery times (e.g., 15-20 sec). In addition, it is recommended that in future studies measurements should include aerobic and anaerobic capacity tests (e.g., the Wingate Anaerobic Test, VO2peak), rather than only outcomes of field tests.

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Comparison on propulsive power asymmetry in basketball players and able bodied subject

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Abstract *Purpose:* To compare the levels of asymmetry in wheelchairs basketball players (WBP) and their counterparts able bodied subjects (ABS). *Methods:* Thirty eight subjects (17 WBP and 21 ABS) were recruited on a voluntary basis to participate in the study after signing an informed consent and proper release of the ethics committee of the University of Pernambuco. All subjects were tested using a compact dynamometer for evaluation of wheelchair propulsive power. The protocol consisted of a maximum effort lasting 20 seconds, performed with synchronous propulsion form. The tires of wheelchairs were calibrated before each test. The WBP used their own sports wheelchairs. The ABS used a wheelchair mounted especially for sports with axle camber set at 0°, in order to reduce the effect of rolling resistance. The maximum power achieved in 20s (POMAX), the maximum power reached the right (POR), the left (POL) and the percentage difference (PODIF) between both sides were analyzed. PODIF was calculated by means of the equation: PODIF = [{(POmáx - POmin) / POmáx} · 100]. The paried t-test and Mann-Withney U test was used to compare variables between groups. Significance level set at 5% (P≤0.05). *Results:* No differences were observed between groups in POMAX, POR and POL (p>0.05). On the other hand, WBP had significant lower percentage differences (PODIF=9%) compared to their counterparts ABS (PODIF=21%). *Conclusions:* we conclude that the sport practice can contribute to the symmetry propulsive power production for wheelchair basketball players.

Barriers and facilitators of sports in people with physical disabilities

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Abstract *Purpose:* The purpose of this study was to determine factors influencing sports participation in people with physical disabilities by comparing barriers and facilitators of sports experienced by active and inactive participants. We also determined which variables had a significant influence on participation in sports. *Methods:* Included were people with physical disabilities that were treated at the Center for Rehabilitation, location Beatrixoord, of the University Medical Center Groningen in the Netherlands between 2009 and 2011. Subjects were invited to complete a (paper or electronic) questionnaire. The questionnaire assessed personal and environmental barriers and facilitators of sports in people with physical disabilities. *(preliminary) Results:* Thirty-nine percent (1224/3170) of the participants completed the questionnaire. Mean age was 53.4 (14.5) years, 50% was male and 58% participated in sports. Popular sports were walking (59%), cycling (58%) and fitness (37%). The disability and fatigue were important personal barriers, although inactive participants experienced their disability and fatigue more often as personal barrier. The cost of sports was the most important environmental barrier. Important personal facilitators for active participants were health, fun and improving strength; advice from medical specialists was the most important environmental facilitator. *Discussion:* The emphasis in a sports program should be on positive aspects of sports, such as fun, health and improving strength, to successfully improve sports participation in people with physical disability. Medical physicians should also facilitate strategies for people with physical disabilities to overcome disability-related barriers or adapted activities to overcome the barrier to stimulate sports participation.

Evidence-based practice in classification: systematic review to revise hand evaluation in wheelchair rugby

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Abstract The aim of this study is to inform the wheelchair rugby classification system through a systematic review of the literature to examine the impact of hand impairment on ball-handling skills in ball sports. Using the meta-analysis of observational studies in epidemiology methodology (MOOSE),[1] search terms were identified with the Patient Interventions Comparison Outcomes (PICO) format to search Medline, CINAHL, Trip Database, and SPORTDiscus (1980 - March 2014). Approximately 1300 articles were identified. After analysis of titles and abstracts for inclusion and exclusion criteria, 54 articles were selected for further analysis. The manual search of article references and quality assessment using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)[2] analysis are underway.

Keywords Hand, hand deformities, hand injuries, neuropathies, spinal cord injury, cerebral palsy, neuromuscular diseases, hand strength, coordination impairment, sensation, articular range of motion, sports, exercise, Activities of Daily Living (ADL), athletes with disabilities, sport for persons with disabilities

Introduction

The use of a classification system in Paralympic sports is essential for minimizing the impact of impairment on the outcome of competition. Classification determines athlete eligibility and groups athletes for competition based on degree of impairment and its impact on sport-specific activities.[3] Thus, the opportunity to win is based on athletic skills combined with physical and mental capabilities of an athlete, rather than degree of impairment. The historical foundation of classification systems is based on the expert opinion of classifiers. In 2007, the International Paralympic Committee (IPC) *Classification Code* outlined the need for international federations to develop evidence-based classification systems through research.[4] In the sport of wheelchair rugby, a systematic review of the literature examined the impact of trunk impairment on performance that informed the development of sport-specific tests for the trunk incorporated in the classification system.[5] To continue advancing the practice of evidence-based research in wheelchair rugby, the aim of this study is to complete a systematic review of the literature that explores the impact of hand impairment on ball-handling skills.

Methods

This systematic review is conducted using MOOSE.[1] The appraisal of eligible study quality is based on STROBE analysis.[2] Articles fulfilling a predetermined minimum set of items with emphasis on methods and results based on STROBE are being selected. Two independent researchers performed the search for articles. A third researcher is available for a final decision in the event of disagreement during article appraisal.

Data sources

Both researchers used Medline (PubMed), CINAHL Complete, and Trip Database (1980 - March 2014). Additionally, one researcher used SPORTDiscus (1980 - March 2014). The following MeSH terms were combined using the PICO format: (P) hand, hand injuries, hand deformities, neuropathies, spinal cord injury, cerebral palsy, and neuromuscular diseases; (I) hand strength, coordination impairment, articular range of motion, sensation; (O) sports, exercise, ADL, and sport for persons with disabilities. A manual search of references may identify additional articles.

Study selection

Impairments in body structure and function relevant to ball skills in wheelchair rugby were identified and considered in the context of gross hand and wrist structure, strength, and coordination required to grasp (span and/or spherical), secure, and release a ball. Hand fine-motor coordination required to complete ball manipulation skills under various conditions was also considered. Inclusion and exclusion criteria for article selection were determined (Table 1).

Table 1.Inclusion and Exclusion Criteria for article selection

Inclusion Criteria	Exclusion Criteria
1. Inclusion of experienced athletes in ball sports 2. Comparison of subjects: • With different types and/ or levels of hand impairment • Able-bodied subjects and those with hand impairment • Compensation for hand impairment and no compensation for hand impairment 3. Quantitative outcome measures that look at hand function: • Specific to ball-handling of experienced athletes • ADL tasks requiring span and/or spherical grasp	1. No definition of level of hand function or only inclusion of an impairment that is not defined as an eligible impairment by the International Paralympic Committee with the exception of sensation[6] 2. Only subjects without impairment are included 3. No comparison between different types of impairment or severity of hand impairment for the defined ball handling skills or ADL, including span or spherical grasp, in-hand manipulation, and precision handling 4. Only qualitative data/expert opinion are in the outcomes 5. Contains only a case report

Quality assessment

The STROBE statement is used to assess the quality of articles eligible for further review. This approach consists of a 22-item checklist used to 'score' study quality. However, suggestions are lacking on a minimum score for inclusion in a systematic review. Therefore, the researchers specifically pre-selected a minimum set of items for inclusion: setting, participants, variables, data sources/measurement, statistical methods, descriptive data, outcome data, and main results. The third researcher makes final decisions in the event of disagreement in scoring.

Results

Initially, approximately 1300 articles were identified. Following examination of the titles and abstracts for inclusion and exclusion criteria (Table 1), 54 articles were identified for potential inclusion in the quality assessment phase (Figure 1). Comprehensive review, manual search of

article references, and crosscheck for overlap are currently underway to complete final article selection and quality appraisal using STROBE analysis.

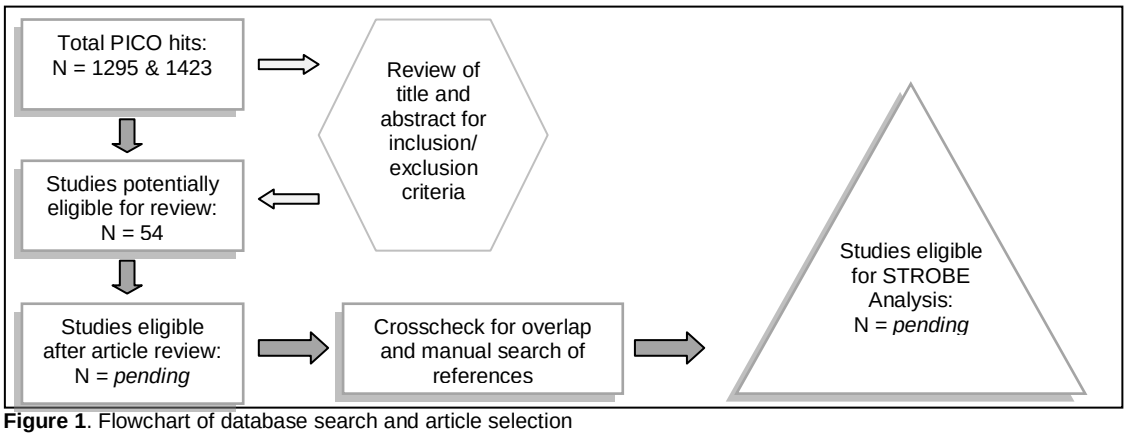

Figure 1. Flowchart of database search and article selection

Conclusion and discussion

Systematic literature review is an important and practical initial step in evidence-based classification. The outcome of this review will contribute to a better understanding of the effect of hand impairment on ball-handling skills. Ultimately, this knowledge will lead to a revision in the evaluation of hand impairment for athletes in wheelchair rugby. Also, the results may guide future research in determining valid and reliable tests of hand impairment and development of standardized ball-handling activities applicable to any ball sport in the Paralympic Movement.

Acknowledgements

Acknowledgement to the International Wheelchair Rugby Federation for support of the classifiers in this research, and to Northern Arizona University for graduate student travel support.

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Oral presentations
Friday, April 25, 2014

Keynote lecture 9: Prof. Dr. J. Rimmer

Framing New Pathways in Post-Rehabilitation Exercise Support Services (PRESS) for People with Disabilities

Rimmer J

The high rates of physical inactivity observed in disabled populations raises growing concern that significant health complications and mounting health care costs will likely occur as more and more individuals live into their later years. Many people with existing and newly acquired neurologic disability have accelerated declines in health post-rehabilitation or as a result of living for many years with a long-term disability. This progressive state of decline has been referred to as Disability Associated Low Energy Expenditure Deconditioning Syndrome or DALEEDS. Reasons for DALEEDS include shorter lengths of stay in rehabilitation and lack of community receptivity in removing many barriers to exercise participation among people with limited income, access to transportation and accessible facilities and programs. Effective prevention of secondary health conditions (eg., DALEEDS, depression, obesity) must begin the moment formal rehabilitation ends. Rehabilitation professionals and fitness trainers both have an important role and responsibility in assisting people with disabilities transition into sport, leisure and generalized physical activity. This paper will describe a model (PRESS) for building a stronger science and practice between rehabilitation and community-based exercise and sport service providers.

Poster presentations
Thursday, April 24, 2014

Swimming fins for Paralympic Athletes

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Abstract *Purpose:* Aim of this study was to develop swimming fins for Paralympic athletes with an amputation for training purposes, in order to increase the performance of the swimmers with respect to using the legs, position in the water and coordination during the stroke. *Methods:* A theoretical biomechanical analysis of front crawl swimming was made for a subject without lower legs. Video analysis under and above the water surface was performed on one athlete during front crawl swimming. The analysis was focused on position of the body in the water and the range of motion of the legs. Results of the analysis were discussed with the National coach of the Dutch Paralympic swimming team, which results in setting goals for the design of the fin. Analysis of the stump and different possibilities of connections to the stump have been tested in an iterative design process. *Results:* The theoretical and video analysis resulted in requirements of the fins. The fins should: 1. Ensure a higher position in the water; 2. Reduce the lateral translation of the hips; 3. Reduce the longitudinal rotation of the hips; 4. Help in delivering propulsion with the legs. Also requirements of the fins with respect to the design were made. Fins should: A. Weigh less than 5 kg; B. Easy to put on and off; C. Be tightly connected to the stump. Fabrication of different prototypes and analyzing the performance resulted in an optimal connection to the stump and helped reaching the training goals. *Conclusion:* Swimming fins for two Paralympic athletes with different types of stumps have been fabricated and tested. The connection to the stump is either realized with liners or Velcro straps, depending on the type of stump. The swimming fin prostheses are lightweight and easy to pull on and off both in and out of the water. The swimming fins allow the swimmer to propel with the legs on a high frequency and with more powerful strokes, which positions the swimmer higher in the water and reduces the hip rotation and translation.

Keywords swimming fins, Paralympic athletes

Introduction

Swimming speed is a function of the propulsion generated from arm strokes and leg kicks. For Paralympic swimmers, with upper and lower limb disabilities, the influence of the kick plays an important role in net force production, in position of the water and coordination. Swimmers with amputations of the limbs have a disadvantage in the generation of propulsion depending on which limb or part of the limb has been amputated (Berger et al., 2001).

Propulsion of Paralympic athletes differs between swimmers, therefor the use of classification systems within Paralympic sports are developed to provide a fair competition for athletes with a range of physical disabilities. In the Dutch national team two swimmers with amputees of the lower leg are classified in category S8. In this category, swimmers who have lost either both hands or one arm are eligible to compete in this sport class. Also, athletes with severe restrictions in the joints of the lower limbs could compete in this sport class.

The head coach of the Dutch Paralympic team had noticed that two of the swimmers of the Paralympic team had difficulties in using their amputated legs in free style swimming. This resulted in less propulsion and a deep position of the body in the water. Propulsion of the legs in free style swimming contributes for around 15% of the propulsion in swimming (Hollander et al., 1988). Leg movement also contributes to a better position of the body in the water resulting in less resistance. For these reasons the coach wants to investigate if training with swimming fins fixed to the amputated legs will improve movements of the legs in swimming races where fins are not allowed.

Aim of this study was to develop swimming fins for two Paralympic athletes with amputations of the lower leg. The swimming fins must be used for training purposes, in order to increase the performance with respect to using the legs, position in the water and coordination during the stroke.

Methods

A theoretical biomechanical analysis of front crawl swimming was made for one of the two subjects (subject A) without lower legs. Subject A was amputated on both legs, just below the knee. Video analysis under and above the water surface was performed for this athlete during front crawl swimming. The analysis was focused on position of the body in the water and the range of motion of the legs. Outcome of the analysis was discussed with the National coach, which results in requirements for the design of the fin. Analysis of the stump and different possibilities of connections to the stump have been tested in an iterative design process.

Results of this design process were also used for developing swimming fins for a second subject (B). Subject B was also amputated on both legs, half way the foreleg; therefore his stumps were longer and thinner than the stumps of subject A. After making prototypes for both subjects, video analysis was performed in order to look for the results while swimming with the fins.

Results

At first, a theoretical and video analysis during free style swimming without fins showed that swimmer A showed a large longitudinal rotation of the hip, a large lateral translation of the hip and a deep position in the water. The theoretical and video analysis resulted in requirements of the fins. The fins should: 1) Ensure a higher position in the water; 2) Reduce the lateral translation of the hips; 3) Reduce the longitudinal rotation of the hips; 4) Help in delivering propulsion with the legs. Also requirements of the fins with respect to the design were made. Fins should: A) Weigh less than 5 kg; B) Easy to put on and off; C) Be tightly connected to the stump.

Different prototypes have been made, which differed in length and connection to the stump. These prototypes were all tested on the subjects and video analyses were made. From the response of the swimmer, the coach and video analysis the conclusion was that the fins should be connected close to the end of the stump. Difficulties were experienced in the connection of the fin to the stump. A fourth generation of prototypes were made with different ways of connections to the stump.



Figure 1. left: prototypes for subject A with liner and Velcro tape; middle: the last prototype with liner for subject A; right prototype for subject B with Velcro tape.

For subject A with short, massive stump two solutions were tested (see figure 1 left). The prototype with Velcro tape used for connection to the stump didn't work out well. The prototype (see figure 1 middle) with a liner and vacuum was a better solution but fixated still not enough.
For subject B, the Velcro tape worked well (figure 1 right). The fins were easy to put on and easy to swim with.

Conclusion and discussion

Swimming fins for two Paralympic athletes with different types of stumps have been fabricated and tested. Analyzing the performance resulted in a sufficient connection to the stump and helped reaching the training goals. The swimming fins allow the swimmer to propel with the legs on a high frequency and with more powerful strokes, which positions the swimmer higher in the water and reduces the hip rotation and translation. The connection to the stump is either realized with liners or Velcro straps, depending on the type of stump. The swimming fin prostheses are lightweight and easy to pull on and off both in and out of the water. Further analysis and optimizing of different ways of connection to the stump will be performed.

Acknowledgements

The authors gratefully acknowledge the subjects of this study Lisa den Braber and Simon Boer for their patience and worth full contribution to the results. They would also like to thank Berend Visser and Sean van der Velde, students Human Kinetic Technology, The Hague University of Applied Sciences, Eemland Perfecta Orthopedie for the assistance and Otto Bock for the liners.

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Effect of gravity compensation on muscle activation in subjects with facioscapulohumeral dystrophy

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Abstract Purpose – Subjects with facioscapulohumeral dystrophy (FSHD) often present disrupted function of the shoulder girdle muscles, which can lead to an impaired arm function and limitations in arm activities. Optimal support during upper extremity (UE) activities can be provided for this target population once a deeper understanding of UE biomechanics and compensatory movement patterns is reached. The aim of this study was to compare differences in muscle activity of subjects with FSHD and healthy controls during standardized tasks with and without using an arm support. Methods – Eleven subjects with FSHD and 8 healthy controls were measured. Participants were asked to perform a set of predefined movements, including two single joint movements at the shoulder (flexion-extension and ab-adduction). Electromyography (EMG) data were obtained from superficial muscles of the shoulder. Maximum EMG activities during the movements, expressed as percentage of maximum voluntary contraction (%MVC), were calculated with and without use of a sling arm support. Results – In the FSHD group, the median EMG activity of the trapezius, deltoid and pectoralis muscles during the single movements was close to MVC activity. When arm support was used, muscle activity generally decreased in all muscles. The average reduction in median muscle activity was comparable for both the control group and FSHD group (37% and 36% respectively). Discussion – The high activity of the trapezius in the FSHD group is an indication of a muscle recruitment mechanism aimed at providing additional arm elevation around 90º. In this position lateral rotation of the scapula is required to further elevate the humerus. However because of the inability to elevate the arm further, the greater muscle activation is an indication of an attempted compensation in the FSHD group. Providing arm support in these positions could therefore reduce muscle effort considerably and should be the object of future research.

Keywords FSHD, Gravity compensation, EMG

Introduction

In facioscapulohumeral dystrophy (FSHD), muscles of the shoulder girdle and the upper arm are often affected (Padberg, Lunt et al. 1991). This disruption of shoulder muscle function is accompanied by shoulder weakness associated with scapular instability, and limitations while performing activities of daily living (ADLs) (Kilmer, Abresch et al. 1995). Upper extremity (UE) support mechanisms can be employed to overcome some of these limitation and to provide functional independence. It has been shown that gravity compensation reduces muscle effort during reaching tasks in stroke patients (Prange, Kallenberg et al. 2009). However, it is currently

unknown how this would affect muscle activation patterns in FSHD patients who suffer from selective muscle weakness. The aim of this study was to compare differences in muscle activity of subjects with FSHD and healthy controls during standardized tasks with and without using an arm support.

Methods

Eleven subjects with FSHD (mean age 33.9±11.5, 4 male, 7 female) and 8 healthy subjects (mean age 49.9±9.8, 5 male, 3 female) were tested on their dominant side. Participants were asked to perform a set of six standardized movements, including shoulder abduction-adduction (SAA) and shoulder flexion-extension (SFE), without assistance and subsequently while being assisted by a passive gravity support mechanism (SLING arm support, Focal Meditech BV, The Netherlands). The SAA and SFE movements were selected, since they are most influenced by gravity. Electromyography (EMG) data were obtained from biceps brachii, deltoid (lateral part), triceps brachii, trapezius (upper part), pectoralis major (clavicular part) and latissimus dorsi muscles. Maximum EMG activities during the movements, expressed as percentage of maximum voluntary contraction (%MVC), were calculated with and without use of a sling arm support.

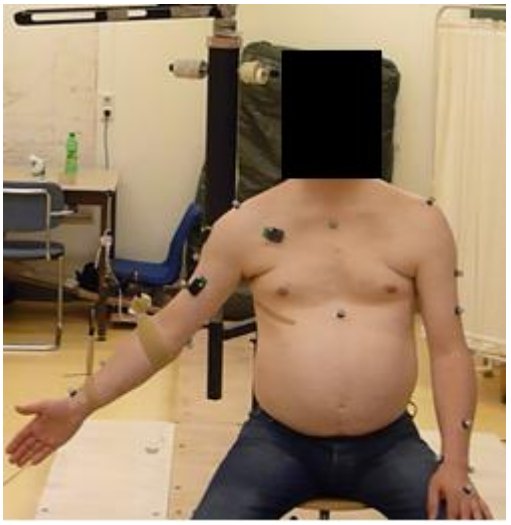

Figure 2. Setup for SLING-assisted movements.

Results

In the FSHD group, the median EMG activity of the trapezius, deltoid and pectoralis muscles during the unsupported SAA and SFE movements was close to the EMG activity during MVC. When the SLING arm support was used, muscle activity decreased significantly in all six muscles that were measured. The average reduction in median muscle activity was comparable for both the control group and FSHD group (37% and 36% respectively).

Table 1. Maximum EMG activation during execution of shoulder flexion-extension and shoulder abduction-adduction in the persons with FSHD with and without arm support. Significant differences between movements with and without SLING are highlighted (*: $p < 0.05$; **:$p < 0.01$)

Movement	Biceps (%MVC)	Deltoid (%MVC)	Triceps (%MVC)	Trapezius (%MVC)	Pectoralis (%MVC)	Latissimus Dorsi (%MVC)
SAA unsupported	16	85	20	115	28	28
SAA supported	6**	46**	12*	47**	9*	9*
SFE unsupported	27	56	17	95	69	69
SFE supported	5**	29**	11**	28**	28**	28**

Discussion and conclusions

This is the first study highlighting the mitigating effect of gravity arm support on muscle activity in persons with FSHD. The high activity of the trapezius in the FSHD group during unsupported movement is an indication of a muscle recruitment mechanism aimed at providing additional arm elevation around 90º. In this position scapular external rotation is required to further elevate the humerus, a movement accomplished by the coordinated action of the upper trapezius and the serratus anterior (Crosbie, Kilbreath et al. 2008). However because of the inability to elevate the arm further, the greater muscle activation found in this study is an indication of an attempted compensation in the FSHD group. Using an arm support appears to decrease this pattern. However to fully understand the underlying compensation mechanism at kinematic and kinetic levels inverse dynamic analysis should be considered in future research (Agarwal, Narayanan et al. 2010).

Acknowledgements

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Elements of an evidence-based training program for upper limb prosthetics

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Abstract The rehabilitation process of patients that received a myo-electric upper limb prosthetic device is divided in two phases: 1) the pre-prosthetic phase, in which the myosignals controlling the prosthesis are trained, 2) the prosthetic phase, in which the use of the prosthesis is trained. In the last years we have studied several aspects of these phases of prosthetic training. The innovative part of this research program is that it takes insights from rehabilitation science and from movement science to develop a training protocol for upper limb prostheses. We will present several of our findings in different stages of prosthetic rehabilitation together with some guidelines for rehabilitation that we derived from those findings. In the pre-prosthetic phase we found that participants differ in the degree to which they can control the rate of change of the myosignals. This implies that not every patient can control a prosthesis with proportional hand opening speed or proportional grip force control. Moreover, we showed that the effect of training was independent of whether this training was done with a real prosthesis, with a virtual prosthesis, or training the patterns of the myosignals presented on a screen.In the prosthetic phase we found that the grasping profile with prosthesis was characterized by a large plateau phase (which is not found in grasping with the natural hand). Training resulted in decreasing the duration of the plateau phase. Moreover, more skilled prosthetic users had a smaller duration of the plateau phase. Hence, rehabilitation should focus on shortening the plateau phase in the grasp pattern. Finally, grip force control is most difficult with a prosthetic hand. Grip force control can improve when objects are first handled with the unaffected hand (in unilateral amputees). The translation of these findings and guidelines into elements of a training program will be discussed.

Assessing Muscle Endurance in Adolescents with Spastic Cerebral Palsy using a Submaximal Repetitions to Fatigue Test

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Abstract The purpose of this study was to compare muscle endurance in adolescents with spastic cerebral palsy (CP) and typically developing (TD) adolescents using a submaximal repetitions-to-fatigue (RTF) protocol. Sixteen adolescents with CP, who were able to walk in and outdoors with or without walking aids, and eighteen TD adolescents within the age range of 12 to 19 years performed three submaximal RTF tests, consisting of series of isotonic knee extension contractions until exhaustion on a computer-controlled dynamometer. The relation between imposed submaximal torque (50-90% of maximal voluntary torque (MVT)) and number of repetitions performed was quantified as the load endurance curve. To display muscle fatigue, surface electromyography (EMG) recordings of the quadriceps muscles were assessed. A mixed linear model analysis showed on average a steeper slope of the relative (%MVT) load endurance curve for the adolescents with CP than the TD adolescents. Substantially lower values were observed for adolescents with CP in the absolute (Nm/kg) load endurance curve. EMG responses did not differ between adolescents with CP and TD adolescents, indicating that both groups seemed equally fatigued at the end of each RTF-test. These results indicate a slightly lower muscle endurance in adolescents with CP compared to TD adolescents on a submaximal RTF-protocol, which is in contrast to earlier observations using a maximal voluntary fatigue protocol.

Keywords Cerebral palsy, muscle endurance, muscle strength, electromyography, dynamometer

Introduction

Individuals with cerebral palsy (CP) more frequently report fatigue as a complaint during activities of daily live than typically developing (TD) peers (Jahnsen, Lisbeth et al, 2003). It is remarkable, however, that recent studies showed lower muscle fatigability, or better muscle endurance, of quadriceps and hamstrings muscles in children with CP compared to TD children using a maximal isokinetic voluntary fatigue protocol (Moreau, Li et al, 2008; Eken, Dallmeijer et al, 2013). The inability of individuals with CP to maximally recruit their muscles might be the cause of this lower muscle fatigability. This limitation could be circumvented using a submaximal fatigue protocol. Therefore, the purpose of the present study was to compare muscle endurance in adolescents with CP and TD adolescents using a submaximal repetitions-to-fatigue (RTF) protocol.

Methods

Subjects

Sixteen adolescents with spastic CP and eighteen TD adolescents (12-19 years old) participated in the study. Adolescents with CP were able to walk in and outdoors with or without walking aids.

Repetitions-to-fatigue protocol

Subjects performed three maximal voluntary isometric knee extension contractions on a computer-controlled dynamometer. The average torque of these three contractions was set as maximal voluntary torque (100%MVT). Afterwards, subjects performed three series of isotonic knee extension contractions against an imposed submaximal load. The three submaximal loads were imposed within a range of 50-90%MVT, to reach a maximum of 25 repetitions before exhaustion. The relationship between the imposed submaximal relative (%MVT) or absolute (Nm/kg) load and the number of repetitions that could be performed until exhaustion was described by the load endurance curve. To monitor muscle fatigue, surface electromyography (EMG) recordings were made of the quadriceps muscles, i.e. m. rectus femoris (BF), m. vastus medialis (VM), and m. vastus lateralis (VL). The increase in normalized amplitude and decrease in median frequency were assessed as indicators of muscle fatigue.

Statistics

A mixed linear model was used to investigate the differences in load endurance curves between adolescents with CP and TD adolescents, including a random slope and intercept. Changes in normalized EMG amplitude and median frequency as a function of repetition number were also analyzed using a mixed linear model, separately for the RTF-test with the lowest load, medium load, and highest load.

Results

Adolescents with CP showed a significantly steeper slope on the relative (%MVT) load endurance curve than TD adolescents (CP, slope=1.21; TD, slope=0.99; p, .018) indicating that with increasing number of repetitions, adolescents with CP showed a larger decrease in the relative (%MVT) load that could be tolerated than TD adolescents (Figure 1 A). In addition, a substantially down shift of the absolute (Nm/kg) load endurance curve was observed for adolescents with CP in comparison to TD adolescents (Figure 1 B, $p<.001$), while the slopes of these curves were similar in both groups. During all three RTF-tests, normalized amplitude increased significantly in the RF, VM and VL adolescents with CP and TD adolescents. During the RTF-tests with the lowest and medium load, a significant decrease in median frequency was observed in the RF, VM and VL in adolescents with CP and TD adolescents.

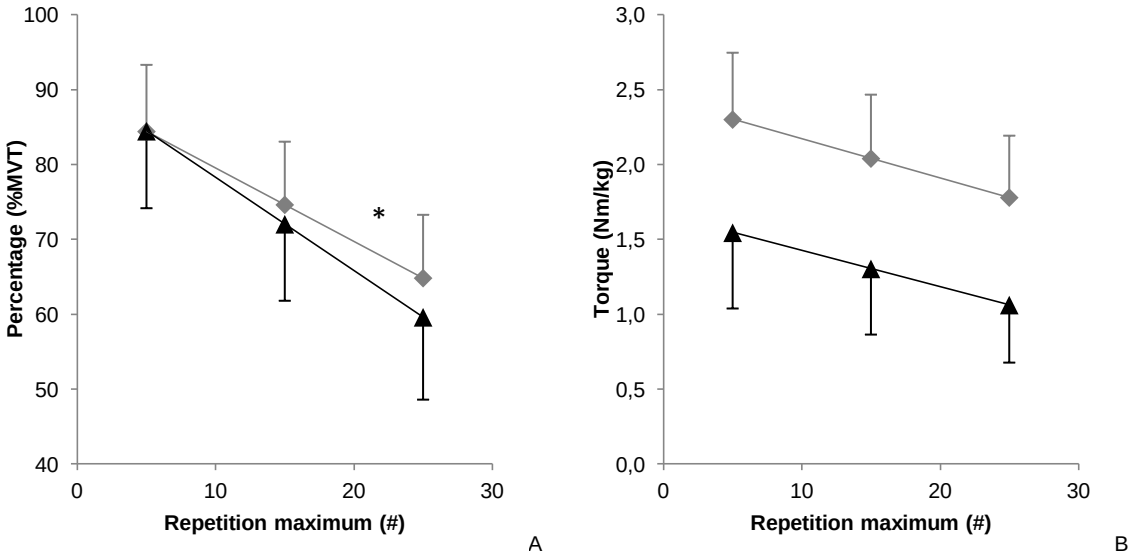

Figure 1. Load endurance curves for adolescents with CP (black line) and TD adolescents (grey line) are plotted for relative (%MVT) torques (A) and absolute (Nm/kg) torques (B). * p<.05.

Conclusion and discussion

In contrast to earlier findings (Moreau, Li, et al, 2008, Eken, Dallmeijer, et al 2013), our results showed slightly lower muscle endurance in adolescents with CP compared to TD adolescents on a submaximal repetitions-to-fatigue protocol. Accordingly, adolescents with CP have somewhat reduced capacity to endure activities at similar relative loads compared to TD adolescents. As becomes apparent from the absolute load endurance curve, adolescents with CP have a considerably reduced ability to sustain absolute submaximal loads, which may affect their ability to perform daily life activities. Adolescents with CP showed similar EMG responses during RTF-tests at different submaximal loads, confirming that both groups were fatigued to the same extend at the end of each RTF-test. In addition to the fact that the RTF protocol circumvents the problem of the inability of individuals with CP to maximally recruit their muscles, this protocol might also be useful to assess the impact of muscle endurance on activities of daily life. Therefore, submaximal muscle endurance testing is recommended over maximal muscle endurance testing.

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The use of simple continuous feedback to increase the ambulatory activity of patients with chronic stroke

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Abstract The purpose of this study was to evaluate whether an objective activity measurement device with simple continuous feedback about activities can facilitate the increase of the daily physical activity of inactive chronic stroke patients. A secondary objective of the study was to test whether the device is user friendly. Nine participants with chronic stroke participated. Participants were asked to test the usability of two different activity measurement devices whereby the purpose, to evaluate the effect of the device to increase the physical activity level, was not mentioned. Each participant participated in the study for 5 weeks and was randomly assigned to a group A or B. The activity level of the participants was measured during three weeks; the baseline (week 1), the blind (wearing a device without feedback), and the feedback condition (a device with feedback). In group A en B the sequence of wearing a device with feedback or wearing a device without feedback was different to exclude cross-over effects. Activity parameters, like activity time, standing time and sitting time, were compared between the three conditions. The user-friendliness of the device was examined during a semi-structured interview and questionnaire. Analyses of the differences between the feedback and blind condition within subjects (using the students' T-Test) revealed a significantly larger activity time (p= 0.004) and activity time per hour (p=0.004) in the feedback condition. The feedback device scored a median of 7/10 on user-friendliness. This study showed that simple continuous feedback can increase the physical activity level of patients with chronic stroke. The used device is reviewed as a user-friendly way to measure physical activity.

Keywords: Physical activity, accelerometers, stroke, objective measurement, persuasive technology, feedback

Introduction

The physical activity level of stroke patients is often low and they have difficulty to initiate activities (Michael, 2007). Therefore, these patients need some extra and continuous support to become more active. Moreover, an active lifestyle prevents against secondary diseases and also reduces the risk of another stroke (Gordon, 2004). A manner to support a person becoming more active is with the use of persuasive technology. Persuasive technology is designed to change a person's attitude or behavior by coaching and motivating a person. Importantly, persuasive technology is based on a voluntary action (IJsselstein,2006) by preferably using tailored messages. Persuasive technology has contributed to a positive effect on physical activity (de Cocker 2012, Fukuoka 2012, King 2008). However, most studies did not use objective data to

formulate messages and information to the participant. The main aim of the study is to indicate if an objective measurement device with simple continuous feedback about their activities can help increase the daily physical activity of inactive chronic stroke patients. Participants were asked to test the usability of two different devices whereby the purpose, to evaluate the effect of the device to increase the physical activity level, was not mentioned. The secondary aim is to evaluate the user-friendliness of the measurement device.

Methods

Data acquisition

Ten participants who had followed a special intensive program at the past at the Sint Maartenkliniek, Nijmegen the Netherlands were included. They all were at least six months post-stroke and had mild to moderate hemiparetic deficits. Each participant participated in the study for five weeks. In week 1 (baseline measurement), the patients wore two Dynaport Minimod tri-axial acceleration sensor in both pockets of trousers to measure their activity level for a week. In week 2 they did not wear the sensors. In week 3 the participants were assigned to either group A or B. Group A wore the same device as in week 1 and did not receive any feedback or instructions (blind condition). Group B wore a PDA device with two acceleration sensors in both pockets of trousers. On the PDA the time they had performed the activities sitting, standing and being active were presented (feedback condition). After a rest week (week 4), group A wore de PDA device and group B the Dynaport device. After week 3 and 5 a short interview was held, which was semi-structured by the use of a questionnaire to assess the user-friendliness of both devices.

Data analysis and statistics

The data were processed by custom made Matlab programs (Frazer 2013). Primary outcome measures were activity time and standing time. One-way repeated measures ANOVA's were used to test the differences in activity parameters between the baseline, blind, and feedback conditions. A student's T-test was used to describe the differences between the blind and feedback condition. The questionnaire consisted of ten 5-point Likert-scale questions. Descriptive statistics were used to describe the outcomes of the questionnaire.

Results

One participants was excluded from the study because he had not enough days measured during the measurement weeks. A repeated measures ANOVA did not reveal any significant differences between the three measurement weeks for any of the activity parameters. However, the Student's t-test revealed a significant difference in activity time ($t(8)=2.44$ $p=0.04$) and activity time per hour ($t(8)=2.68$ $p=0.003$) between the feedback and blind condition. The activity time (mean: 63 min (SD 41.5) and activity time per hour (mean 4.9 min (SD 3.2) in the feedback condition was larger than in the blind condition (mean 53 min (SD 39) and mean 4.1 min (SD 2.9)). Standing time did not reveal any significant differences. The PDA device scored a median overall score of 7/10 on user-friendliness. Five of the nine participant stated that they may buy the PDA device if it was commercially available. One of the recommendations was to make a smaller PDA and sensors.

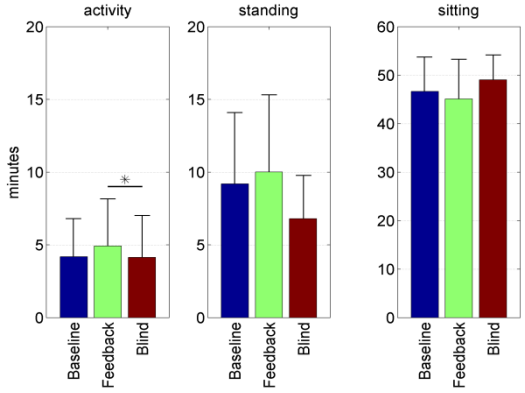

Figure 1. *Overview of total sitting, standing and activity of the participants per hour for each of the measurement weeks. *significant difference.*

Conclusion

Although the investigated group was small, the current study showed that simple continuous feedback is a promising tool to increase the activity level of a patient with chronic stroke. The system is user-friendly, but the smaller the size of the PDA and accelerometers, the more convenient it will be.

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Scaling of anaerobic performance by fat free mass in paraplegic and tetraplegic athletes

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Abstract To examine differences in the anaerobic exercise performance of wheelchair athletes and to investigate the relationships between functionality and power output during wheelchair propulsion. Fifteen wheelchair elite athletes, trained in wheelchair basketball (7 paraplegics and 1 amputee) and rugby (7 tetraplegics), were recruited to participate in this study. Participants were rated on a scale ranging from 1 to 15 due to their functionality according to their medical records and by a GB physiotherapist (rugby ratings 1-6, basketball ratings 9-15). Peak power (PP) and mean power (MP) were determined during a 30-s anaerobic wheelchair ergometer test. Fat free mass (FFM) was obtained from dual energy X-ray absorptiometry. Wheelchair basketball players had a significantly higher absolute PP and MP than rugby players ($P<0.05$). PP corrected for FFM maintained this difference between groups (Basketball 1.52±0.31W/kg, Rugby 1.02±0.14W/kg, $P<0.05$), and the same trend was observed for MP. However, PP/FFM and MP/FFM remained fairly constant across functionality ratings for both wheelchair rugby (regression slope 0.002) and basketball players (regression slope -0.010). On the other hand, absolute or body mass corrected PP and MP resulted in positive trends when compared to functionality rating. Correcting PP and MP with FFM results in a measure which can be used to compare anaerobic performance of individuals with differing functionality. Both for wheelchair rugby and basketball athletes, the average scores of PP/FFM and MP/FFM are fairly independent of the functionality rating. This measure has therefore advantages over the classical indicators of anaerobic performance (absolute power in W or body mass corrected power in W/kg), which seem to increase as functionality improves. We assume the underlying reason to be that FFM takes active metabolic mass of athletes with a disability best into account when compared with the classical indicators.

Keywords wingate, DEXA, wheelchair basketball, wheelchair rugby

Introduction

Wheelchair athletes display a higher proportion of fat-free soft tissue mass and corresponding lower proportion of fat mass, when compared to their non-disabled counterpart (Goosey-Tolfrey and Sutton, 2012). Moreover, when considering the wheelchair athlete the level of spinal cord injury (SCI) will also influence the degree of regional FFM distribution due to muscle atrophy, bone demineralisation and fat storage associated with paralysis.

It has been demonstrated that wheelchair sprint performance is highly dependent on the functionality of individuals (i.e, disability and training status) (Goosey-Tolfrey and Leicht, 2013). Scaling procedures, which may facilitate performance comparison between individuals in

wheelchair propulsion, exist (Goosey-Tolfrey et al. 2003). However, they have so far focused on aerobic performance only and not taken into account any measures of functionality. Therefore the aim of the present study was to examine differences in the anaerobic exercise performance of wheelchair basketball and wheelchair rugby athletes and to investigate the relationships between functionality and power output during wheelchair propulsion.

Methods

Participants
Fifteen wheelchair elite athletes, trained in wheelchair basketball (7 paraplegics and 1 amputee) and rugby (7 tetraplegics), were recruited to participate in this study. Participants were rated on a scale ranging from 1 to 15 due to their functionality according to their medical records and by a GB physiotherapist (rugby ratings 1-6, basketball ratings 9-15). Approval for the study was obtained from the University Research Ethics Committee and the National Research Ethics Service. Athletes were excluded from participation in the study if they had a pre-existing medical condition that would be adversely affected by exposure to ionising radiation, if they had been subject to high levels of ionising radiation exposure (e.g. radiotherapy) in the last 12 months, or if they had regular contact with ionising radiation (e.g. work environment).

Dual energy X-ray absorptiometry (DEXA) examinations: On arrival at the laboratory, body mass was measured to the nearest 0.1 kg, using wheelchair beam scales (Marsden MPWS-300, Henley-on-Thames, UK). Participants wore loose fitting, light weight clothing with no metal or reflective material and all jewellery and prostheses were removed where possible. Participants were asked to identify any metal fixtures (e.g. surgical pins), prior to the scans being performed. Each individual was aligned supine on the bed and appropriately positioned, as closely as possible to the standard protocols, given the limited range of motion in some participants, whilst attempting to minimise positions that might produce spasms or other movement and any discomfort. Velcro restraints were applied around athletes' knees and ankles to minimise movement during the scan, unless this was not possible because of the disability. Body composition was assessed using a *Lunar Prodigy Advance* DEXA scanner (GE Lunar, Madison, WI, USA) running version 12.20, *Encore 2006* software. Standard quality assurance and stability monitoring of the DXA scanner was performed with daily measurement of the GE-Lunar calibration block and aluminium/water bath spine phantom prior to the use of the machine, to detect and correct for any drift. All scans and analyses were performed by the same trained operator. Values of fat free mass (FFM) were calculated for the total body, the arms (left and right), the trunk, the upper body (trunk and arms) and the lower limbs.

Sprint Performance: All participants were tested in their own sports wheelchair using a wheelchair ergometer (WERG) interfaced with a computer (Compaq Armada 1520, Series 2920A). The WERG consisted of a single roller (length, 1.14 m; circumference, 0.48 m) and a flywheel sensor connected to the roller. Each participant performed a deceleration test and power output (PO) was calculated using the principles described by Theisen et al. (1996). For further details of this procedure please refer to Lenton et al. (2008). Participants completed a 5-minute warm-up prior to the test starting at a self-selected propulsion velocity. The anaerobic performance test involved participants to propel their wheelchair on the WERG as fast as they could for a period of 30s. The test was conducted from a 1.5 $m.s^{-1}$ rolling start, and the initiation of the test was on a '3,2,1' countdown. For all tests, the peak velocity was achieved within ten seconds of the start of the test. Peak power (PP) and mean power (MP) were recorded (in Watts) and were calculated relative to the body mass of the participant and relative to total body FFM.

Results

Wheelchair basketball players had a significantly higher absolute PP and MP than rugby players ($P<0.05$). PP corrected for FFM maintained this difference between groups (Basketball 1.52±0.31W/kg, Rugby 1.02±0.14W/kg, $P<0.05$), and the same trend was observed for MP. However, PP/FFM and MP/FFM remained fairly constant across functionality ratings for both wheelchair rugby (regression slope 0.002) and basketball players (regression slope -0.010). On the other hand, absolute or body mass corrected PP and MP resulted in positive trends when compared to functionality rating.

Conclusion

Correcting PP and MP with FFM results in a measure which can be used to compare anaerobic performance of individuals with differing functionality. Both for wheelchair rugby and basketball athletes, the average scores of PP/FFM and MP/FFM are fairly independent of the functionality rating. This measure has therefore advantages over the classical indicators of anaerobic performance (absolute power in W or body mass corrected power in W/kg), which seem to increase as functionality improves. We assume the underlying reason to be that FFM takes active metabolic mass of athletes with a disability best into account when compared with the classical indicators.

Acknowledgements

We thank the Great Britain Wheelchair Rugby and Basketball Associations for their support. Appreciation is extended to all sportsmen who volunteered to participate in this study, the DEXA technical input of Dr Katherine Brooke-Wavell and the help of Mhairi Keil and Dr Louise Croft.

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Nutritional supplement habits and perceptions of disabled athletes

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Abstract *Purpose:* The purpose of this study was to determine: (1) the prevalence and type of nutritional supplements (NS) used by disabled athletes; (2) reasons for their use; (3) where athletes obtain information regarding NS; and (4) how athletes perceive NS use. *Methods:* The NS questionnaire was completed by 399 athletes (296 M, 103 F) with a disability (42% spinal cord injury, 19% amputee, 11% cerebral palsy, 10% visually impaired, 18% les autres) representing 23 sports and 21 nationalities. Participants completed the questionnaire anonymously via an online portal or using a paper version. *Results:* Fifty-eight percent of athletes used at least one NS in the previous six month period and 40% follow the instructions on the label to determine dose. Nine percent experienced a negative effect from using NS. The most popular NS were protein, sports drinks, multivitamins and carbohydrate NS which were used by 26%, 20%, 14% and 13%, respectively. The most prevalent reasons for use were recovery, energy and to improve strength/power, and the 3 most used sources of information were nutritionist, coach and training partner. The most common outlets to obtain NS were the supermarket, internet and health food/sport shops. Elite level participants are more likely to use NS, which is unlikely due to the pressure to perform but may reflect greater access to nutritionists. The pressure to use NS and a 'more is better' culture appears to be minimal. Only 67% of elite athletes reported attendance at an educational workshop, while 52% of all athletes wanted more information regarding anti-doping and NS. *Conclusion:* The use of NS is prevalent in the disabled athletic population. It is clear that more disability-specific information on NS is required and would be welcomed. Education should be focused on coaches and athletes themselves. Further research on the use of NS by disabled athletes is needed to provide evidence-based recommendations and to reduce the amount of 'trial and error'.

Field-based testing for aerobic performance in wheelchair dependent youth with spina bifida

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Abstract *Background:* Youth with Spina Bifida (SB) who are wheelchair dependent have reduced levels of physical fitness compared to typically developing and ambulating peers with SB. To gain insight in physical fitness and to evaluate exercise programs, standardized measurement protocols should be made available. *Purpose:* The primary objective of this study was to examine the validity and reproducibility of the 10-m Shuttle Ride Test (SRiT) in wheelchair dependent youth with SB. The secondary objective was to determine the predictive value for VO_{2peak}. *Methods:* Twenty-eight children with SB (14 ♂, 14♀), mean age 14.0 (±3.6) years, who use a manual wheelchair for daily life or sports participated. All performed the SRiT and the Incremental Rollerband Protocol (IRP), 13 performed a second SRiT. For validity, $VO_{2peak}$and HR_{peak} were compared using paired t-tests and Pearson correlation coefficients. For reproducibility, the intra-class correlation (ICC), the smallest detectable change (SDC) and the limits of agreement (LOA) were calculated for VO_{2peak} and number of achieved shuttles. Prediction of VO_{2peak} was determined with a stepwise linear regression analysis. *Results:* VO_{2peak} and HR_{peak} during the SRiT and the IRP were highly comparable; no significant differences were found and correlations ranged from r=0.72 to r=0.77 ($p<0.05$). ICCs for VO_{2peak} and number of achieved shuttles were excellent (0.95 to 0.99). Narrow LOA and small SDC values indicate good agreement. The number of completed shuttles was the best and only predictor of VO_{2peak} (=5.77 + 1.23 * shuttles; $R2$=0.48). *Conclusion:* The SRiT is a valid and reproducible test to measure aerobic performance in wheelchair dependent youth with SB. However, the predictive value for VO_{2peak} is limited, since aspects as wheelchair skills also contribute to the number of achieved shuttles. Therefore, the number of achieved shuttles may be used as an evaluative outcome measure for overall physical performance.

A New Lower Leg Prosthesis To Improve Lateral Balance In Prosthetic Walking

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Abstract In current prosthetic leg designs, the part of a prosthetic leg between the prosthetic foot and the stump or artificial knee is a rigid stick. Because of this, prosthetic walkers cannot change the direction of the ground reaction force in the frontal plane on the prosthetic leg during walking. It is proposed to replace the rigid stick by a bar mechanism that is placed between the foot and stump or artificial knee. The prototype uses the hip strategy in a more efficient manner than classic designs, thereby enabling prosthetic walkers to produce more horizontal ground reaction and change the centre of pressure under the foot during the stance phase on the prosthesis. In this way, the prototype is likely to improve lateral balance in prosthetic walking.

Keywords Lateral Balance Control, Prosthetic Walking, Prototype, Centre of Pressure, Horizontal Ground Reaction Force

Introduction

The walking pattern of prosthetic walkers differs from that of unimpaired humans. The lack of active muscle control, especially at the prosthetic foot, leaves prosthetic walkers unable to actively change the centre of pressure (CoP) under the foot during the stance phase on the prosthesis (Hof et al. 2007). The resulting deficient lateral balance control forces prosthetic walkers to compensate by changing their gait parameters. For instance, they tend to stand longer on their sound leg and have a wider stride on the prosthetic side (Jaegers et al., 1995, Hof et al. 2007). Further, they tend to bend their trunk towards the prosthetic side when walking (Jaegers et al., 1995). In order to improve lateral balance control in prosthetic walking a new, patented prosthetic prototype has been developed at the Center for Human Movement Sciences, University of Groningen, the Netherlands.

Prototype

The prototype replaces the tube between the prosthetic foot and knee or stump socket, as is present in most of the current prosthetic designs available on the market. It is connected distally at the prosthetic foot and proximally at the knee (above knee amputation) or the socket (below knee amputation). By means of universal connection points the prototype can be connected to existing stump sockets, prosthetic knees, and prosthetic feet (Figure 1). The mechanism is suited both for above and below knee amputees, as long as the level of amputation is high enough. The prototype consists of nine metal bars and six hinges, and allows for sideways motion in the frontal plane only (one degree of freedom). In contrast to the addition of a simple hinge joint between the prosthetic foot and knee/socket, which will result in rotation and instability, the sideways motion of the mechanism adds both rotation and translation of the leg with respect to the foot. The sideways motion arises when after contraction of the muscles at the hip moments of force arise, which rotate and translate the leg. This can be seen as either abduction or adduction of the hip. The foot will respond with a much smaller counter rotation, resulting in a combined functional change in horizontal ground reaction force (hGRF, or shear force) and CoP. By using the muscles around the hip joint in a more efficient manner than with classic prosthetic designs, the prototype allows for active lateral balance control.



Figure 1. Lateral (left) and frontal (right) views of the prototype, mounted between a prosthetic (right) foot and knee.

State of the art

Over the course of 2014, multiple gait analyses will be performed. The prototype will first be tested on healthy individuals wearing a prosthetic simulator (Kneewalker) and after that on amputees. In both cases a direct comparison between a classic prosthetic set-up and the prototype will be made, outcome measures being functional variations in hGRF and CoP during the stance phase of walking on the prosthetic leg. It is hypothesized that with the prototype small functional variations should be visible in the CoP pattern under the prosthetic foot during the stance phase of walking (see Figure 2). This is much like the found CoP patterns in unimpaired walking. Currently, measurements with a healthy population walking on the Kneewalker are in progress.

Expectations

Expectations are that the prototype enables prosthetic walkers to actively change their CoP under the foot during the stance phase on the prosthesis. This will lead to increased lateral balance control, which will result in better performance of activities of daily living, an improved safety during walking, and an improved quality of life.

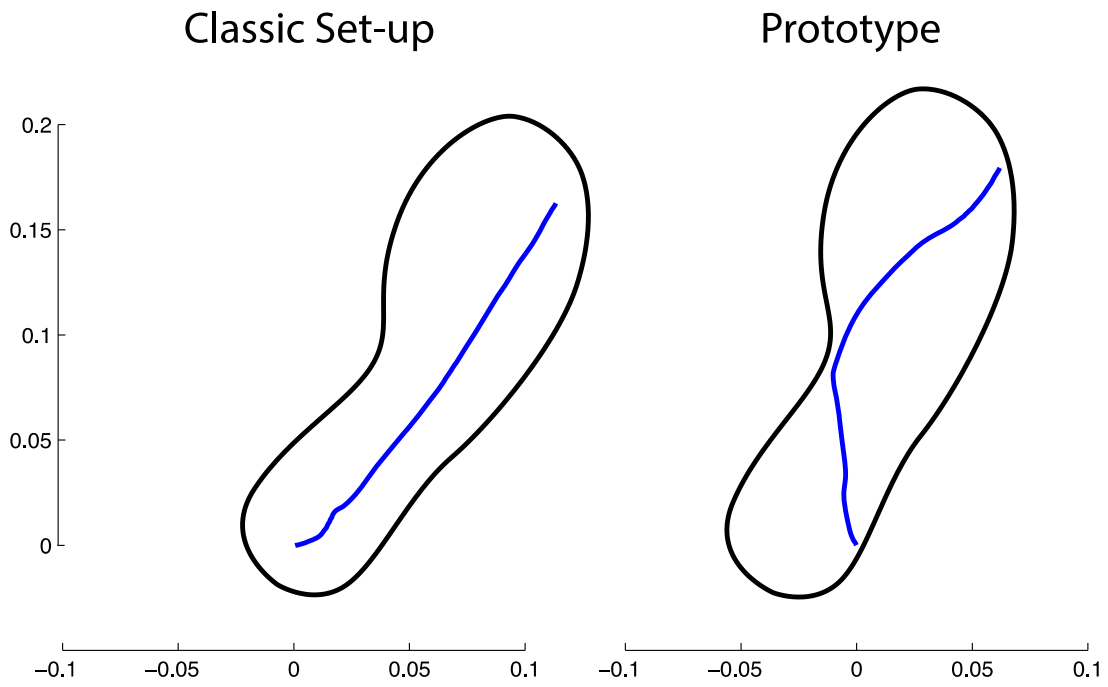

Figure 2. Expected differences in CoP trajectories during the stance phase on the prosthesis (right leg) between a classic prosthetic set-up and the prototype. Axes are in metre. The figures represent the stance phase on the prosthetic (right) foot, whilst stepping to the lateral side with the unimpaired (left) foot. Regardless of this directional change and shear forces exerted through the hip muscles, a classic set-up (left hand figure) will result in a stereotypical, usually straight CoP pattern. This in contrast to the prototype (right hand figure), which will respond to exerted shear forces by a dynamically changing CoP pattern that will be different with each step.

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Age-Related Changes to Wheelchair Efficiency and Peak Power Output in Novice Able-Bodied Males

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Abstract *Purpose:* To determine the effect of age on sub-maximal wheeling efficiency and peak power output in able-bodied males inexperienced with wheelchair propulsion. *Methods:* Healthy young (n=10, 21-30 yrs) and older (n=8, 66-80 yrs) male subjects participated in this study. All subjects had no prior manual wheelchair experience. The primary outcome measures were gross mechanical efficiency (GME) and Mechanical Effectiveness (ME), during 5 min of sub-maximal wheeling. GME is the ratio between power output and physiological energy expenditure, while ME is ratio of tangential force over total force. We also measured various kinetic values during the sub-maximal wheeling as well as peak power output (PPO) during a sprint test. Differences in these three parameters between the age groups were evaluated using t-tests. *Results:* There were no statistically significant differences in the sub-maximal efficiency measures of GME ($p>0.05$). Significant difference were observed in ME and peak power output [ME= 0.74 ± 0.12 vs 0.62±0.08 ($p=0.022$); PPO = 449.33±158.51 vs 251.95±106.04 (W) ($p=0.008$)], for younger and older adults respectively. *Discussion:* Although there is evidence that older adult cardiovascular function decreases with age, this deterioration may not necessarily correlate with musculoskeletal decrease. Our study showed a decline with the mechanical or kinetic outcomes but no change in gross mechanical efficiency. This is poor relationship between the two is consistent with recent work by Lenton et al (2013). Our findings suggest that healthy older individuals can have similar cardiovascular capacity as younger populations but their mechanical effectiveness and strength reduce the ability to propel manual wheelchairs particularly during maximal wheeling conditions.

Keywords wheelchair propulsion, energy expenditure, biomechanics, wheelchair skills, older adults, able-bodied

Introduction

A recent Statistics Canada Census has shown that the number of Canadians 65 and over has increased 14.1% between 2006 and 2011 to almost 5 million people.[1] The increasing size of this older population makes it increasingly important to research the ways in which it differs from other age groups, in order to increase the quality of care to this population through targeted treatments or mobility aid prescriptions. To date there has been a large body of literature on the general decline of various physical functions such as upper body endurance, power and strength in elderly populations when compared to younger populations [2,3,4] but there has been limited research on the task-specific physiological responses to manual wheelchair use. One study that

has evaluated the effect of age on upper body aerobic performance while wheeling was done by Sawka et al. This study evaluated maximal power output, peak oxygen uptake and maximal heart rate, and found significant reductions with age in all 3 variables. [5] Though this is a valuable study, there are a number of limitations. The type of disability is not standardized across the different age groups, with the majority of the younger population having a SCI, and the majority of the elderly population having arthritis or a broken hip. As individuals with SCI have less muscle mass and lower resting energy expenditure compared to able-bodied populations, these factors could have effected their aerobic performance differently when compared to the other participants with different conditions[6]. More research is needed evaluating differences in wheeling ability with age.

The purpose of this study was to evaluate the differences in submaximal wheeling efficiency, using gross mechanical efficiency and mechanical effectiveness, and peak power output in older and younger subjects. We hypothesized that all 3 variables would be reduced in older populations based on previous research on age-related physical capacity declines.

Methods

Two age groups were recruited for this study: 19-40 years of age for the younger adult group, and 65+ years of age for the older adult group. Able-bodied males without any prior manual wheelchair experience were recruited. Exclusion criteria included: 1) previous experience using a manual wheelchair 2) any history of cardiovascular disease 3) any history of upper extremity pain and/or surgeries 4) arthritis 5) any history of smoking or respiratory disease and 6) diabetes. There were 2 phases to this study: measuring submaximal efficiency values and measuring peak power output during wheeling. There were two submaximal efficiency values used: gross mechanical efficiency (GME%) and mechanical effectiveness (ME%). GME% is defined as the ratio between power output and energy expenditure, and mechanical effectiveness is a measure of biomechanical efficiency, and is defined as the ratio of force directed in a tangential direction to total force outputted. These values were tested during a 5 minute propulsion phase on a wheelchair treadmill at 3 or 4 km/hr at 0° grade. Gross mechanical efficiency calculations were taken using a metabolic cart as well as power output values taken from a force-sensing wheel called the SmartWheel, while the mechanical effectiveness values were also measured using the SmartWheel. The second phase of testing, measuring the peak power output of the participants was measured via the SmartWheel during a 15 meter wheelchair sprint test down a hallway. This test was performed twice with a 2 minute rest period between the trials, and an average was taken between the trials. A comparative statistical analysis was performed between the groups for the variables used in the study. An independent t-test and a Mann-Whitney U test were used on parametric and non-parametric data respectively. Level of significance was set at $p<0.05$.

Results

Ten younger male subjects and eight older male subjects were tested. There were no statistically significant differences in the submaximal efficiency measure of gross mechanical efficiency (GME%), however there was a significant difference in mechanical effectiveness (ME%) for efficiency and the sprint test's peak power output, with ME%= 0.74 ± 0.12 and 0.62±0.08 ($p=0.022$); PPO = 449.33±158.51 and 251.95±106.04 (W) ($p=0.008$), for younger and older adults respectively.

Discussion

The goal of this study was to compare the difference in physiological and biomechanical function during wheeling in between older and younger adult male, inexperienced wheelchair users. While there is a large amount of evidence in the area of maximal exercise capacity to show differences in older and younger adults abilities [2,3,4], there is a lack of research in changes in sub-maximal mechanical efficiency with age, particularly in the area of wheelchair use. Our results showed that at sub-maximal wheeling speeds, there was no significant difference in gross mechanical efficiency, which is contrary to previous findings [5]. Although we did not see a physiological efficiency improvement we did observe a purely biomechanical improvement with mechanical efficiency improved in younger people which is more consistent with Karamaker et al [7] and their work on wheeling velocity. The mechanical or musculoskeletal declines may be more dramatic than the cardiopulmonary function as one ages.

Conclusion

Our findings suggest that healthy older individuals can have similar physiological efficiency as younger populations but their mechanical effectiveness and strength reduce the ability to propel manual wheelchairs in certain scenarios, particularly during maximal or more difficult wheeling situations.

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Upper body training and exercise: Low intensity handcycling

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Abstract Purpose: Though ACSM guidelines can be used as a basis to train the upper body, risks on overuse injuries are present for wheelchair users when training at too high intensities too soon. The purpose of this study was to determine whether lower intensity (30%HRR) handcycling training improves physical capacity and whether this is perceived as achievable (low perceived discomfort and effort). Methods: 19 able-bodied, untrained healthy females (age 18-23) were included. 9 received handcycling training (experimental group (EG); 7 weeks, 30% HRR, 30 min per session, three times per week) and 10 received no training (control group (CG)). All subjects performed an incremental pre- and post-test performed on an add-on handbike on a motor driven treadmill. Peak values for oxygen uptake (VO2), peak power output (PO), ventilation (VE), heart rate (HR), and submaximal values for mechanical efficiency (ME) at 41W, as well as HR and VO2 (at 55W) were assessed during both tests. Local perceived discomfort (LPD) and rate of perceived exertion (RPE) were measured. Results: TG showed an improvement in POpeak (pre: 81.1 ± 11W; post: 97.4 ± 11.3W) and HRpeak (pre: 182 ± 11 bpm; post: 188 ± 11 bpm) compared to CG. Improvements for ME (pre: 12.7 ± 0.7; post: 16.6 ± 1.7), VO2 (pre: 1148 ± 117 ml/kg/min; post: 955 ± 133 ml/kg/min), VE (pre: 37.6 ± 6.1 l/min; post: 28.3 ± 4.5 l/min) and HR (pre: 163 ± 15 bpm; post: 154 ± 12 bpm) were found. Participants scored low on RPE (7.1 ± 0.5; very very light) and LPD (3.4 ± 1.6; no discomfort) during training. Conclusion: Low intensity handcycling training seems to improve physical capacity with low physical discomfort. However, VO2peak did not increase. ME increased after low intensity training allowing greater mobility in 'daily life' exercise. In particular early in the rehabilitation process, when risks on injuries are high, low intensity handcycling training seems to provide interesting opportunities in pursuing a healthy lifestyle.

Keywords: Rehabilitation, physical capacity, local perceived discomfort, gross-efficiency, peak power output

Introduction

How to optimally train the upper body is a particularly relevant question for those in a wheelchair. Recent studies provided evidence indicating that handcycling could be a promising exercise mode of upper-body training in the context of a healthy lifestyle (Hettinga et al. 2010). The upper body muscles are alternatingly active (front and back) through the full circular movement of handcycling. Consequently, the task load during handcycling is spread over time and muscle groups, and no high peak loads occur (Arnet et al. 2012a,b). This means that risks of overuse injuries associated with exercise and training are very low compared to hand rim wheelchair

propulsion, where incidence of shoulder complaints is high (van Drongelen et al. 2006). Therefore, handcycling seems to be an ideal training mode to improve mobility for persons in early rehabilitation while preventing overuse injuries at the same time. However, to adequately train the upper body, training guidelines specific for the upper body need to be designed.

Though not fully applicable to handcycling and disability sports, general training guidelines as prescribed by the ACSM (Garber et al. 2011) can be used as a starting point for developing training guidelines more specific for upper-body exercise in general as well as for persons with a disability such as a spinal cord injury (Hettinga et al. 2013). However, physiological responses and strain of handcycling are expected to differ from activities that exercise the large muscle groups of the lower body, and therefore it is important to study effects of various training programs in a controlled and standardized way. To understand, individualize and optimize upper-body training, different training programs must be evaluated in persons in a wheelchair, as well as in the able-bodied. Reference data from able-bodied are necessary to better understand the physiology of the upper body in relation to exercise and training using handcycling, and to facilitate the interpretation of data from the range of patients/disabilities (Hettinga et al 2013 JSCM).

As already indicated, in designing upper body training programs, one aspect that needs to be incorporated is the risk on overuse injuries of the upper body. Risks on overuse injuries are present when training at too high intensities too soon, even when performed in the promising training mode of handcycling; Early in their rehabilitation process, patients with traumatic injuries are usually not familiar with arm propulsion, and care must be taken with prescribing adequate training. Therefore, the purpose of this study was to determine whether lower intensity (30%HRR) handcycling training improved physical capacity and whether this is perceived as achievable (low perceived discomfort and effort) in untrained able-bodied women.

Methods

19 able-bodied, untrained healthy females (age 18-23) were included. Nine participants received handcycling training (experimental group (EG); 7 weeks, 30% HRR, 30 min per session, three times per week) and 10 received no training (control group (CG)). All subjects performed an incremental pre- and post-test performed on an add-on handbike on a motor driven treadmill. Peak values for oxygen uptake (VO_2), peak power output (PO), ventilation (VE), heart rate (HR), and submaximal values for mechanical efficiency (ME) at 41W, as well as HR and VO_2 (at 55W) were assessed during both tests. Local perceived discomfort (LPD) and rate of perceived exertion (RPE) were measured.

Results

The TG showed an improvement in PO_{peak} (pre: 81.1 ± 11W; post: 97.4 ± 11.3W) and HR_{peak} (pre: 182 ± 11 bpm; post: 188 ± 11 bpm) in comparison with the CG. Also improvements for submaximal ME (pre: 12.7 ± 0.7; post: 16.6 ± 1.7), VO_2 (pre: 1148 ± 117 ml/kg/min; post: 955 ± 133 ml/kg/min), VE (pre: 37.6 ± 6.1 l/min; post: 28.3 ± 4.5 l/min) and HR (pre: 163 ± 15 bpm; post: 154 ± 12 bpm) were found. The participants scored on average low on RPE (7.1 ± 0.5; very very light) and LPD (3.4 ± 1.6; no discomfort) during the training sessions.

Conclusion

Low intensity handcycling training seems to improve physical capacity with low physical discomfort. Also, literature has shown that handcycling is less straining and requires lower peak forces compared to handrim propulsion. Low intensity handcycling training thus seems to improve physical capacity with a relatively low risk on shoulder injuries. However, VO2peak did not increase and fitness thus did not seem to improve. Lastly, at submaximal level, ME increased after low intensity training. This allows greater mobility and possibilities in 'daily life' sub-maximal exercise intensities. It thus seems that, in particular early in the rehabilitation process, when risks on injuries are high, low intensity handcycling training provides interesting opportunities in pursuing a healthy lifestyle. More research is required to test and develop other training programs such as interval training, strength training, different exercise intensities of endurance training and concurrent training in able-bodied exercisers, to further develop a reference base to better understand and interpret data from a wide range of disabilities. In addition, to be able to advise and design training for each individual wheelchair user, more research on training in wheelchair users with specific disabilities is required as well, as not much is known on training effects in relation to various disabilities.

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Motor learning with lever-propelled wheelchairs: effect of three weeks of practice on technique

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Abstract *Purpose:* Lever-propelled wheelchairs could be useful alternatives or additions to using hand-rim wheelchairs. For the implementation of lever-wheelchairs, knowledge about the effects of practice on technique is needed. Effects of three weeks of practice on technique were studied. *Methods:*Inexperienced able-bodied male participants were randomly divided over an experimental (n=8) and a control group (n=8). The experimental group performed seven natural learning practice trials spread over the three weeks. Practice trials consisted of two 4 minute exercise blocks, with 2 minutes of rest in between. Pre- and posttest were three weeks apart for both training and control group and consisted of three blocks of 4 minutes of exercise, with 2 minutes of rest in between. All tests were done in a wheelchair equipped with the NuDrive lever mechanism on a motorized treadmill at submaximal intensity (0.30 W/kg, 1.11 m/s). Outcome variables for technique were: stroke frequency, push time, cycle time, percentage push time/cycle time and their coefficients of variation. *Results:* Stroke frequency decreased (-12 strokes/min, p=0.022), and cycle time increased (+0.12s, p=0.030), over time in both groups. Push time increased more in the experimental group compared to the control group (+0.11s vs.+0.02s, p=0.022). Besides the changes in timing, participants became more stable in their movements as evidenced by lower coefficients of variation (CV). The CV of stroke frequency decreased over time in both groups (-1.8%, p=0.015). The CV of push time (-4.4% vs. -0.2%, p=0.030), cycle time (-3.6% vs. -0.5%, p=0.027) and percentage push time/cycle time (-3.9% vs. +0.9%, p=0.018) decreased more in the experimental group compared to the control group. *Conclusion:* Technique shifted towards a slower and more stable pattern after three weeks of practice. The largest change was found in the push phase: participants seemed to be more inclined to change timing and stability in the active phase than the passive phase.

Keywords Lever-propulsion, motor-learning, technique

Introduction

Upper body pain has been reported to be present in 73 % of the manual wheelchair users (1). This upper body pain and related overuse injuries can have detrimental effects on the life of wheelchair users. These problems can decrease the overall functioning of wheelchair users and increase the risks for cardiovascular problems, diabetes and obesity (2). Lever-propulsion is an alternative to hand-rim propulsion that could potentially help to decrease or even prevent the overuse injuries and shoulder pain issues associated with hand-rim propulsion.

Lever-propulsion is suggested to have various advantages that could help to prevent overuse injuries and shoulder pain issues. Research has shown lever-propelled wheelchairs to be more efficient and less straining compared to handrim-propelled wheelchairs (3). However, disadvantages of lever-propelled wheelchairs are that they are in general large, heavy and hard to maneuver (4). The NuDrive lever-mechanism (Pure Global ltd, United Kingdom) attempts to improve on these disadvantages of lever-propulsion compared to hand-rim propulsion. Potential advantages of the NuDrive are that patients can propel themselves with an upright trunk and a continuous grip. The upright position can potentially help to prevent back problems. The continuous grip can potentially help wheelchair users with limited hand functions.

For the successful implementation of lever-propelled wheelchairs, knowledge about the effects of practice on technique is required first. For the prevention of injuries and the minimization of discomfort of new wheelchair users, it is important that wheelchair propulsion is learned correctly and efficiently. Therefore, we investigated the effects of three weeks of practice with the NuDrive on technique.

Methods

Design

Inexperienced able-bodied male participants, age: 21,6 (1.7) were randomly divided over an experimental (n=8) and a control group (n=8). The experimental group performed seven natural learning practice trials spread over the three weeks. Practice trials consisted of two 4 minute exercise blocks, with 2 minutes of rest in between. Pre- and posttest were three weeks apart for both training and control group and consisted of three blocks of 4 minutes of exercise, with 2 minutes of rest in between. All tests were done in a wheelchair equipped with the NuDrive lever mechanism on a motorized treadmill at submaximal intensity (0.30 W/kg, 1.11 m/s).

Outcome variables

Outcome variables for technique were: stroke frequency, push time, cycle time, percentage push time/cycle time and their coefficients of variation.

Statistics

Repeated measures ANOVA and independent t-tests were performed. A $p<0.05$ was considered to be significant.

Results

Table 1. Technique variables: timing (* significant interaction, #significant time effect)

	Stroke Frequency (stroke/min) #		Push Time (s) # *		Cycle Time (s) #		Percentage Push Time/Cycle time (%)	
	Exp	con	exp	con	exp	con	Exp	con
pre	69.8 (9.6)	77.7 (11.3)	0.40 (0.07)	0.35 (0.06)	0.88 (0.13)	0.79 (0.12)	45.2 (3.4)	44.5 (1.8)
post	59.7 (14.3)	73.4 (13.9)	0.51 (0.10)	0.37 (0.07)	1.07 (0.27)	0.85 (0.16)	48.1 (4.4)	43.9 (4.0)

Table 2. Technique variables: timing (* significant interaction, #significant time effect)

	CV Stroke Frequency (stroke/min) #		CV Push Time (s)# *		CV Cycle Time (s)# *		CV Percentage Push Time/Cycle time (%) *	
	Exp	con	exp	con	exp	con	exp	Con
pre	8.6 (5.5)	7.4 (3.6)	11.6 (4.5)	12.1 (4.1)	9.2 (4.5)	7.6 (3.4)	10.1 (4.6)	9.3 (2.4)
post	5.7 (3.4)	6.9 (2.5)	7.2 (1.6)	11.9 (3.4)	5.6 (2.9)	7.1 (3.0)	6.2 (2.7)	10.2 (4.1)

Stroke frequency decreased and cycle time increased over time in both groups. Push time increased more in the experimental group compared to the control group. Besides the changes in timing, participants became more stable in their movements as evidenced by lower coefficients of variation (CV). The CV of stroke frequency decreased over time in both groups. The CV of push time, cycle time and percentage push time/cycle time decreased more in the experimental group compared to the control group.

Conclusion

Technique shifted towards a slower and more stable pattern after three weeks of practice. The largest change was found in the push phase: participants seemed to be more inclined to change timing and stability in the active phase than the passive phase.

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Reliability and sensitivity of the Dutch Movement-Specific Reinvestment Scale in clinical stroke patients

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Abstract Stroke patients are said to have an increased tendency to consciously control their movements, or "reinvest". Since this tendency may affect successful rehabilitation, an instrument is needed that can reliably assess reinvestment in clinical stroke patients. We investigated the reliability of a Dutch translation of the 6-point Likert-scale version of the Movement-Specific Reinvestment Scale (MSRS). In total, 36 clinical stroke patients (< 1 year post-stroke) and 37 healthy age-matched controls completed the translated MSRS on two occasions, separated by 1 week. The MSRS comprises 10 statements, referring to the "Movement Self-Consciousness" (MSC) and "Conscious Motor Processing" (CMP) subscales. Reliability was assessed by calculating the test-retest reliability, internal consistency, and limits of agreement. The results showed test-retest reliability to be high for the total test score both for stroke patients (α = .82) and controls (α = .90). Internal consistency of the MSC and CMP subscales was adequate for patient (.79 and .68, respectively) and control groups (.65 and .68, respectively). A change in mean total reinvestment score of 1.3 (patient group) and 0.7 (control group) points can be considered a change greater than measurement error. Awaiting confirmation in a larger sample, these results suggest the Dutch 6-point Likert version of the MSRS to be a reliable tool to assess reinvestment in clinical stroke patients.

Keywords Stroke, Reinvestment, Conscious Motor Control, Movement-Specific Reinvestment Scale

Introduction

Many stroke survivors report the need to consciously control their movements in order to ensure successful movement execution. This phenomenon is also termed 'reinvestment' (Orrell, Masters, & Eves, 2009): attempting to consciously control movements by reinvesting explicit movement-related knowledge. Paradoxically, stroke patients' increased tendency to reinvest may exacerbate rather than alleviate their existing motor impairments. Reinvestment has been associated with an increased risk of falling in healthy elderly (Wong, Maxwell, Masters, & Abernethy, 2008) and with greater functional impairments in chronic stroke patients (Orrell et al., 2009). However, as these studies were retrospective (Wong et al., 2008) and cross-sectional (Orrell et al., 2009) it remains unclear whether functional impairments are actually caused by increased reinvestment, or vice

versa. Also, we do not know at what point in rehabilitation patients' increased disposition to reinvest becomes manifest.

To elucidate the putative role of reinvestment in motor rehabilitation of stroke patients, we need an instrument that allows reliable assessment of this construct already from the start of rehabilitation. One instrument that might serve this purpose is the English Movement-Specific Reinvestment Scale (MSRS; Masters, Eves, & Maxwell, 2005). However, this scale has only been used in chronic patients (> 1 year post-stroke; Kleynen et al., 2013; Orrell et al., 2009). In the present study, we translated the original English MSRS into a Dutch version with 6-point Likert scale answer possibilities and assessed its reliability in clinical stroke patients (<1 year post-stroke).

Methods

Participants

In total, a number of 36 clinical stroke patients and 37 age-matched healthy controls were included. Patients were included if they have suffered a stroke less than 12 months ago, received rehabilitative care at Heliomare (both in- and outpatient), and were able to understand instructions and provide informed consent.

Materials

A Dutch translation of the English MSRS was used. The English MSRS includes 10 items, with five relating to the construct of feeling self-consciousness about moving (Movement Self-Consciousness subscale) and the other 5 items relating to conscious motor control (Conscious Motor Processing subscale). Items are scored on a 6-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree).

Procedure

The original MSRS was translated into Dutch in accordance with the recommendations outlined by Guillemin, Bombardier and Beaton (1993). Stroke patients and healthy controls completed the translated MSRS on two occasions, one week apart. This relatively short period was chosen to minimize differences in motor and cognitive function of patients between measurements. When necessary, the items and answer possibilities were read out loud by one of the investigators.

Data Analysis and Statistics

Mean reinvestment scores were calculated for the total scale and both subscales for each participant. Statistical analyses were performed separately for both groups. Test-retest reliability was assessed with a 2-way, random effect, consistency, single measures ICC for the total reinvestment score as well as both subscales. Internal consistency was calculated with Cronbach's alpha for both subscales. Reliability was deemed satisfactory when ICC and Cronbach's alpha values are 0.7 or higher. Measurement error of the total reinvestment score was assessed by calculation of Bland Altman's limits of agreement.

Results

Characteristics of both groups are shown in Table 1.

Table 1. Group Characteristics.

	Stroke Patients (n=36)	Healthy Controls (n=37)
Age (years ± SD)	57.19 ± 11.7	61.05 ± 9.7
Sex (Male/Female)	16 / 20	14 / 23
Time since stroke (days ± SD)	76.17 ± 64.6	
Aphasic/Non-aphasic	9 / 26	
Location of stroke		
Right	12	
Left	18	
Bilateral	2	
Stem/Cerebellar	3	
Basal Ganglia	1	

Reinvestment scores

For stroke patients, mean total reinvestment was high on both occasions (T1 = 4.16, T2 = 3.91), with higher scores on the CMP (T1 = 4.74, T2 = 4.52) than MSC (T1 = 3.57, T2 = 3.29) subscale. Healthy controls showed lower total reinvestment scores (T1 = 2.23, T2 = 2.02), while showing a similar pattern of higher scores on the CMP (T1 = 2.64, T2 = 2.37) than MSC subscale (T1 = 1.83, T2 = 1.66).

Table 2. Test-retest reliability and internal consistency results for both groups.

		Stroke Patients	Healthy Controls
Test-Retest (95% CI)			
	Total Score	0.82 (0.68-0.91)	0.91 (0.83-0.95)
	Movement Self-Consciousness	0.86 (0.74-0.93)	0.82 (0.68-0.90)
	Conscious Motor Processing	0.63 (0.39-0.79)	0.90 (0.82-0.95)
Internal Consistency			
	Movement Self-Consciousness	0.79	0.65
	Conscious Motor Processing	0.68	0.68

Reliability

Overall, satisfactory test-retest reliability and internal consistency was found for the stroke group (Table 1), although the CMP subscale scored slightly below the cut-off value of .7 on both reliability tests. Test-retest reliability was somewhat higher for the healthy control group (all > .8) while internal consistency was similar. Analysis of the limits of agreement revealed that a change in mean total reinvestment score of 1.3 (patient group) and 0.7 (control group) points can be considered a change greater than measurement error.

Conclusion

The MSRS was found to be a reliable instrument to assess reinvestment of clinical stroke patients (> 1 year post-stroke). Satisfactory reliability was found for the total test score and MSC subscale. The low reliability of the CMP subscale may be due to small range in responses: on average each subject scored above 3. Limits of agreement were acceptable, with an average 1.3-point change being greater than measurement error. Considering that almost 80% of inpatient stroke survivors that met the inclusion criteria completed the study, and considering that 25% of these patients were aphasic, results seem to be generalizable to the general clinical

stroke population that is admitted to a rehabilitation center. Therefore, although awaiting confirmation in a larger sample, results suggest the Dutch 6-point Likert version of the MSRS to be a reliable tool to assess reinvestment in clinical stroke patients. Future studies may consider using this scale to further explore the relationship between reinvestment and recovery of motor function after stroke.

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Patterns of change in wheelchair exercise capacity in the first years after spinal cord injury

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Abstract *Purpose*: 1) to identify different patterns of the change of wheelchair exercise capacity in the period between the start of active spinal cord injury (SCI) rehabilitation and five years after discharge; 2) to examine determinants of the patterns of the change of exercise capacity. *Methods:* Design: Prospective cohort study. Measurements at the start of active inpatient rehabilitation (start), three months later (3M), at discharge of inpatient rehabilitation (discharge), one year (1Y), and five years after discharge (5Y).Setting: Eight rehabilitation centres in The Netherlands.Participants: 130 persons with SCI, aged 18-65, and wheelchair-dependent at least for long distances.Interventions: Not applicable. Main outcome measures: Wheelchair exercise capacity: Peak Power Output (POpeak (W)). *Results:* We found four different patterns of the change of POpeak (means (standard deviation)): (1) HIGH-PRO (33% of total study group): high progressive scores (Start: 49 W (15.0) – 5Y: 77 W (17.2)), (2) DETER (12%): progressive scores during inpatient rehabilitation with deteriorating scores after discharge (Start: 29 W(8.7) – Discharge: 60 W(8.4) – 5Y: 39 W (13.1), (3) LOW-PRO (52%): low progressive scores (Start: 20 W (10.1) – 5Y: 31 W (15.9)), and (4) LOW-RISE (3%): low inpatient scores with strong progressive scores after discharge (Start: 29 W (15.5) – 5Y: 82 W (10.6)). Logistic regression of factors that might be distinctive between HIGH-PRO and LOW-PRO revealed that older age, female gender, tetraplegic lesion and low functional status were associated with LOW-PRO. DETER showed more neuropathic pain and lower sports participation compared to HIGH-PRO. *Conclusion:* Wheelchair exercise capacity after SCI shows for the vast majority a positive trend and can be described in distinct patterns dependent on personal, lesion and functional characteristics.

Feasibility and reliability of maximal arm crank ergometry testing in wheelchair dependent children with childhood onset disabilities

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Abstract The purpose of this pilot study is to determine the feasibility and reliability of maximal exercise and sprint testing with an arm crank ergometer (ACE) in wheelchair dependent children with Spina Bifida and Cerebral Palsy.
Maximal exercise and sprint testing using ACE seems feasible and reliable in wheelchair dependent children with SB and CP, despite a large variability in functional abilities. Because of the small sample size a study with a larger group is necessary to confirm these results.

Keywords: maximal exercise test, wingate, arm crank ergometer, children, wheelchair, spina bifida, cerebral palsy

Introduction

Children with childhood onset disability are less active compared to typically developed children. (Takken T, van Brussel M et al. 2008) and have a higher energy cost of locomotion and lower physical fitness. The development of their musculoskeletal and cardiovascular system is influenced by this lower physical activity. In addition, limitations in the physical fitness can influence a child's ability to be physical active and to participate in activities of daily living. This particularly applies to children who are wheelchair dependent. To prevent a cycle of decreased physical activity and fitness it is recommended to monitor the aerobic and anaerobic fitness levels in this population. Children who rely on a wheelchair for their daily activities due to their physical disability are in most circumstances not able to perform regular fitness tests on a treadmill or cycle ergometer. An alternative method is an arm ergometer. In adults this method is used in different diagnose groups such as spinal cord injury, cerebral palsy and multiple sclerosis. Arm crank ergometry has also been used in children to assess aerobic and anaerobic fitness (Unithann VB, Katsimanis G et al. 2007; Klimek-Piskorz E, Piskorz C et al. 2006) but there is limited information on the feasibility and reliability of these tests in wheelchair dependent children with more severe impairments. Information about reliability is especially important to determine whether measured differences are due to training or within the error of measurement.

The purpose of this pilot study is to determine the feasibility and reliability of maximal exercise and sprint testing with an arm crank ergometer (ACE) in wheelchair dependent children with Spina Bifida and Cerebral Palsy.

Methods

Six wheelchair dependent adolescents with Spina Bifida (SB, n=3) and Cerebral Palsy (CP, n=3), aged 14 to 18 years (height ranged from 1.44-1.80m), performed a 20s-Wingate sprint test, followed by an incremental maximal exercise test on an ACE (Angio, Lode bv, Groningen). Children with pulmonary, cardiac or neuromuscular disease were excluded. The protocols were first tested in typically developed children (n=7, age 8-12) Based on these tests, an arm span of less than 1.40m was added as an additional exclusion criterion for the wheelchair dependent children. The wheelchair was positioned in front of the arm crank ergometer and fixated by the brakes and a wedge. Before the sprint test, a warming-up of 3 minutes was performed including three short (5s) sprints to familiarize to the cycle ergometer and determine the optimal sprinting load. Maximal sprint power was measured over a period of 20 seconds, with peak (P20peak), and mean power (P20mean) as the main outcome measures. After a cooling down of 3 minutes and 20 minutes of rest the aerobic fitness was measured with an incremental maximal exercise test. Every minute the resistance was elevated until maximal effort was achieved. The incremental steps of the maximal exercise test were, based on the pilot tests in typically developing children, set at 3-8W. Peak oxygen uptake (VO_2peak), maximum power output (POmax), respiratory exchange ratio (RER), and maximum heart rate (HRmax) were measured. To determine the test-retest reliability the tests were repeated within a 1-3 week period. Feasibility was assessed by the capability to perform the tests and for the maximal exercise it was determined whether they achieved maximal effort. Perceived exertion was measured using the Borg scale for both tests and estimated by the researcher. If a child was unable to perform a test, reasons for premature ending of the test were documented. Intraclass correlation (ICC) and standard error of measurement (SEM) were calculated for P20peak, P20mean, VO_2peak and POmax.

Results

All participants were able to perform both tests. One subject did not complete the second test because of personal circumstances. Reasons for the children to stop during the maximal exercise test were peripheral muscle fatigue (n=6), shortness of breath (n=3), cramp in arms (n=1) and bladder dysfunction (n=1). In most tests (n=10) maximum effort was achieved, except in one case, because of bladder dysfunction. The Borgscale ranged between 7.5 to 10 for the maximal exercise test, and between 7 to 9 for the Wingate. One child had to perform the test with one arm, because his most affected side was not able to grip the arm crank handle. He was able to perform the test and achieved maximal exertion. In 3 cases it was important to keep coaching the children to maintain a steady rhythm during the exercise test. With respect to cognitive ability, they have to be able to follow instructions and keep on exercising. Analysis showed a mean RER of 1.10±0.096 (range 0.92-1.26) and a HRmax between 148 to 205 bpm (mean 183±17). Results for the test-retest reliability are shown in table 2 (Wingate) and 3 (maximal exercise test). ICC values of the Wingate test were 0.93 (95%Confidence Interval 0.49-1.00) for P20peak and 0.96 (95%CI 0.63-1.00) for P20mean. SEM values expressed as percentage of the mean were 8.9% for P20peak and 6.0% P20mean. For the maximal exercise test ICC for VO_2peak were 0.83 (95% CI 0.20-0.98) and for POmax 0.86 (95%CI 0.35-0.99). The SEM values were 7.1% for the VO2peak and 10.6% for POmax.

Table 1. Results Wingate test (n=5)

	Occasion 1 (mean ± SD)	Occasion 2 (mean ± SD)	ICC	SEM	SEM %
P20peak (W/kg)	2.72 ± 1.19	2.53 ± 0.82	0.93	0.23	8.9%
P20mean (W/kg)	1.82 ± 0.68	1.77 ± 0.62	0.96	0.11	6.0%

Table 2. Results Maximal exercise test (n=5)

	Occasion 1 (mean ± SD)	Occasion 2 (mean ± SD)	ICC	SEM	SEM %
VO_2peak (ml/min/kg)	25.8 ± 4.9	27.5 ± 4.7	0.83	1.89	7.1%
POmax (W/kg)	0.97 ± 0.26	1.05 ± 0.36	0.86	0.30	10.6%

Conclusion and discussion

Maximal exercise and sprint testing using ACE seem to be feasible in wheelchair dependent adolescents with SB and CP with an arm span of at least 1.40 m. The test could not be performed in smaller children (arm span < 1.40m) with the current equipment. The load increments of the maximal exercise test were lower than previously advised for arm crank ergometry in typically developing children. Therefore lower incremental steps should be considered when testing this group. Reliability seems acceptable but a study with a larger group is necessary to confirm these results and to determine whether the SEM is small enough to detect changes over time.

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Anaerobic exercise testing in rehabilitation patients: a systematic review

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Abstract *Purpose:* The purpose of this study was to systematically review the literature about tests for investigating anaerobic capacity in adults with Spinal Cord Injury (SCI), Cerebral Palsy, stroke-injury, amputations, and wheelchair users. *Methods:* MEDLINE, CINAHL, and Web of Science were searched. No time or language restrictions were applied. Papers were included if anaerobic measurements were performed on subjects which met the abovementioned criteria for adults with disabilities. Papers were excluded when anaerobic capacity was derived from aerobic tests only, if 'stroke' and 'anaerobic' were used in a context differing from that of the scope of this study, and/or if papers consisted of reviews or conference presentations. All steps in the assessment were performed by two independent observers. *Results:* Of the 132 papers found, 47 were included in this review. Tests can be distinguished between upper- and lower extremity testing. Upper extremity testing (n=48) can be separated between arm crank (n=14) and wheelchair testing (n=34). Different types of modified Wingate (mWAnT) protocols and sprint tests, a MW-HIE- and a Force-Velocity Relationship test for anaerobic assessment of the upper extremity were found. In lower extremity testing (n=9), bicycle (n=2), recumbent (n=1), and testing without using devices (n=6) can be distinguished on which mWAnT, sprint tests and jump tests were performed. In most studies, mWAnT and sprint tests were performed, with protocols varying on duration, initial velocity and applied resistance. In most studies, study population consisted of wheelchair bound SCI patients. A slight majority of the studies tested disabled athletes instead of less physically active patients. Only two studies investigated anaerobic capacity in the early rehabilitation phase, one study tested shortly after discharge. *Conclusion:* Anaerobic capacity in impaired individuals is generally tested by using mWAnT and sprint tests, with modified protocols. Since no consistency was found in methods used, future research should focus on a standardized protocol for measuring anaerobic capacity in people with disabilities.

Keywords Anaerobic capacity, Disabilities, Exercise test

Introduction

Physical capacity, defined as the physiological ability to perform activities of daily living and leisure, is determined by the capacity of the physiological- and neurological system. Physical capacity can be expressed by aerobic capacity, anaerobic capacity, muscle force, flexibility and balance (Van Velzen et al., 2006). Anaerobic capacity is the ability to generate energy by metabolising creatine phosphate and by glycolysis, without using oxygen.

According to Haisma et al (2006), standardized assessment of physical capacity is necessary for the effective prediction and evaluation of progress of the physical capacity in future. Additionally, monitoring changes in physical capacity may give an indication of the effectiveness of rehabilitation programmes (Balemans et al., 2013; Haisma et al., 2006). It was found that in impaired individuals motor activities of daily living (ADL) are of short duration and therefore utilize the anaerobic metabolism. Therefore, testing anaerobic capacity seems to be very beneficial in impaired people. However, in clinical practice, today only aerobic capacity is measured frequently. In literature, no standardized protocols for measuring anaerobic capacity in the impaired are available. Therefore the aim of this study is to systematically review the protocols used for measuring anaerobic capacity in people suffering from different impairments (spinal cord injury (SCI), cerebral vascular accident (CVA), lower limb amputation, adults with cerebral palsy (CP), and wheelchair users).

Methods

Search strategy

An electronic database search was conducted by using PubMed, CINAHL and Web of Science. In this search, no time and language restrictions were applied. A combination of the free text words Anaerobic capacity, -performance, -power, -test, sprint performance, spinal cord injury, CVA, amputation and wheelchair was used.

Study selection

Articles were included if they met all of the following inclusion criteria: (1) Subjects were spinal cord injury and/or stroke patients and/or lower limb amputees and/or cerebral palsy patients and/or able-bodied subjects using wheelchairs, (2) Anaerobic capacity was measured, (3) Description of the protocol was available, (4) Outcome parameters were defined, (5) Impairment was reported, (6) Study was published as a full paper, and none of the following exclusion criteria: (1) Age<18 years, (2) Anaerobic capacity was derived from aerobic test, (3) Stroke was used in relation to other meanings than CVA, (4) Paper was about anaerobic bacteria or antibiotics, (5) Study population consisted of animals, (6) Review or conference presentation. The assessment was performed by two independent assessors (L.A.K and T.A).

Results

After removing duplicates, title-, abstract- and full text screening and reference check, 47 of 132 papers were included in this study. Anaerobic capacity was measured in both upper (n=48) and lower extremity (n=9). In upper extremity anaerobic testing, five different sorts of test can be distinguished, while three different tests can be distinguished in lower extremity anaerobic testing (figure 1). Upper extremity anaerobic testing is performed using arm crank ergometers and wheelchairs, while lower extremity testing is performed using bicycle or recumbent ergometers, or without using devices.

For measuring anaerobic capacity, especially modified Wingate (mWAnT) protocols are found by using arm crank (n=14), wheelchair (n=22), bicycle (n=2), and recumbent ergometers (n=1). Moreover, different types of sprint tests, with a fixed distance or a fixed duration, were performed often, using wheelchairs (ergometer, over ground and on a treadmill) (n=12) and without using devices (n=4). Furthermore, a FV-relationship test, a Mechanical Work in a High Intensity Exhaustion Exercise (MW-HIE), and two jump tests were found for assessing anaerobic capacity in impaired people.

Conclusion and discussion

Mainly, the MWAnT and sprinttest were found to be used for assessing anaerobic capacity. However, a large variety was found within these protocols. Within the mWAnT protocols, distinctions can be made based on duration. While the original Wingate test lasts 30s, protocols ranging from 5 until 30s were found in this review. Furthermore, differences were found in applied resistance. In most studies, resistance was based on scaling to body weight (0.10-1.0 N/kg), as in the original Wingate test (Bar-Or, 1987). Moreover, resistance is based on predictions of anaerobic capacity calculated from isometric strength, simulations, and constant resistances (0.8 -22 N). Lastly, different mWAnT protocols can be differentiated based on initial velocity. Although the original Wingate test had a rolling start, nine studies started from zero velocity. The different sprint tests found ranged from 10-30s and 10-100m.

From this literature research can be concluded that a heterogeneity of protocols was found for determining anaerobic capacity in impaired people. The level of anaerobic capacity is very heterogeneous between people suffering from different impairments, with different ages, and different activity levels. Therefore standardization of protocols, which can be individualized by for instance applying different resistances, is essential for anaerobic testing in impaired individuals and should therefore be of increased attention in future research.

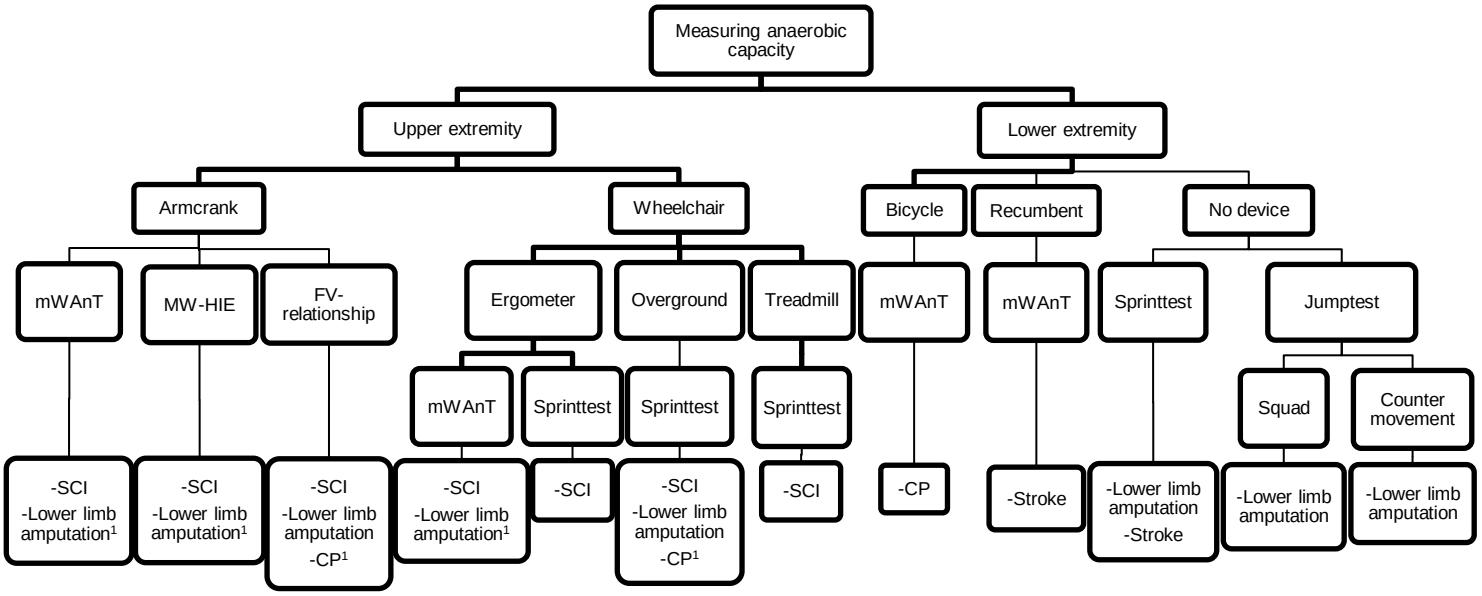

Figure 1. Schematic representation of tests found for measuring anaerobic capacity in patients. [1]Test is performed on a more homogeneous population. Only main impairments are presented

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Effects of hybrid cycling on body composition and knee bone density in spinal cord injury

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Abstract *Purpose:* The purpose of this study was to investigate the effects of a 16-wk hybrid cycle training intervention on body composition and knee bone mineral density (BMD) in inactive people with a long-term spinal cord injury (SCI). *Methods:* Nine participants with SCI (8 male, 1 female, age 52 ± 8 yrs, time since injury 20 ± 9 yrs) were randomly assigned to the hybrid cycle group (N = 5) or handcycle group (N = 4). Participants in the hybrid cycle group were trained two times a week for 16 weeks on a hybrid cycle, in which functional electrical stimulation (FES)-induced leg exercise is combined with voluntary arm exercise. The participants in the handcycle group performed the same training program on a handcycle and served as control group to establish the additional training effects of active involvement of the legs. The main outcome measures were soft tissue composition of the legs, fat mass of the trunk and BMD of the knee, measured using dual-energy X-ray absorptiometry (DXA).*Results:* Significant interaction effects for lean mass (p = 0.009) and fat percentage (p= 0.020) of the legs. The hybrid cycle group showed an increased lean mass (+441gram, +6,5%) and decreased fat percentage (-2.5%), while the handcycle group showed an decreased lean mass (-291gram, -5.0%) and an increased fat percentage (+0.3%) of the legs . Analysis of the fat mass of the trunk and knee BMD revealed no significant main effects for time (p = .388, p = .124, respectively) or interaction effects (p = .579, p = .318, respectively). *Conclusion:* The hybrid cycle training intervention induced positive body composition changes in the legs, while the handcycle training intervention did not. The idea considering a more beneficial effect of hybrid training over handcycle training in decreasing the amount of trunk fat or increasing knee BMD was not proven in this study since these parameters did not significantly change after either kind of training intervention.

Keywords: spinal cord injury, hybrid exercise, body composition, bone mineral density

Introduction

People with spinal cord injury (SCI) are forced into a sedentary lifestyle which results in secondary complications like an altered body composition and a decreased bone mineral density (BMD) below the lesion level. Individuals with SCI have less fat-free mass and greater fat mass, and the fat mass is more centrally located (Spungen, Adkins et al. 2003), making these individuals more susceptible for cardiovascular diseases. The decreased BMD results in osteoporosis and an increased risk of bone fractures (Jiang, Dai et al. 2006). Physical exercise can be a solution for diminishing these problems. However, people with SCI have difficulties reaching a sufficient exercise intensity due the relatively small available active muscle mass during training. The use of functional electrical stimulation (FES) makes it possible to activate the

paralyzed lower-limb muscles and induce greater training responses. In this study, we focused on hybrid exercise in which FES-training is combined with upper-body exercise. The aim of the present randomized controlled trial is to investigate the effects of a 16-wk hybrid cycle versus handcycle training intervention on knee BMD and body composition in people with a long-term SCI.

Methods

Participants

Nine people (8 male, 1 female) with SCI were included in the study. The participants were 26-65 years of age, had a spastic paraplegia or tetraplegia for at least 10 years (age at onset ≥ 16 years) and were physically inactive.

Design

Participants were randomly assigned to the hybrid cycle group (N = 5) or handcycle group (N = 4).The hybrid exercise training was performed on the BerkelBike (BerkelBike Pro, BerkelBike B.V., St. Michielsgestel, the Netherlands), while the control group was trained on a handcycle (Speedy-Bike, Reha-Technik GmbH, Delbrück, Germany). During the hybrid exercise, synchronous hand cycling was combined with asynchronous FES-induced leg cycling. Both groups underwent a 16-wk training program in which the participants were supposed to train two times per week which resulted in a total of 32 workouts. Training sessions were performed on an ergotrainer (Taxc Flow, Techinische Industrie Tacx B.V., Wassenaar, the Netherlands). Participants were instructed to train between level 4-7 on the 10-point Borg scale. During a training session, the intensity could be changed by the participant by adjusting the speed, or by the trainer changing the gear or the resistance of the ergotrainer. The intensity of the hybrid cycle group could also be adjusted by changing the current amplitude (15-150mA). Main outcome measures were fat mass, lean mass and fat percentage of the legs, fat mass of the trunk and BMD of proximal tibia and distal femur. All these measures were obtained using dual-energy X-ray absorptiometry (DXA)

Statistics

The effect of the 16-wk hybrid cycle training program on the outcome measures (dependent factors) was assessed by a two-way mixed design ANOVA. The independent factors were training group and pre-posttest. Significant interaction effects were further analyzed with (in)dependent t-tests. All data were analyzed with SPSS (version 18.0) and the significance level for all tests was set at p=0.05.

Results

Fat mass analysis of the legs revealed a significant main effect for pre/posttest (p=.036). The fat mass of the legs decreased on average 159 g, 95% CI [13.8, 305,4]. No interaction effect was found. Lean mass analysis of the legs showed no main effects for pre/posttest (p = .486), but there was a significant interaction effect (p = .009). The lean mass in the hybrid cycle group increased with 441 g, 95% CI [-870.4, -12.1], from pre- to posttest, while the lean mass in the handcycle group tended to decrease (p = .092). Fat percentage analysis showed a trend for more percentage of fat in the pretest compared to the posttest (p = .055). A significant interaction effect (p = .020) was found in the hypothesized direction. The fat-percentage of the legs in the hybrid cycle group decreased (-2,5%) while the fat percentage in the handcyle group did not (+0,3%)

Analysis of the BMD of proximal tibia and distal femur, and the fat mass of the trunk did not reveal any significant main effects or interaction effects. Additional analysis of the data of trunk fat mass revealed that the hybrid cycle group lost on average 516 g of fat mass from pretest to posttest, while the handcycle group lost only 117 g. However, due to the large standard deviations this difference was not significant.

Conclusion and discussion

A 16-wk hybrid cycle training intervention has positive effects on soft tissue composition of the legs in people with a SCI. This has several advantages for people with SCI, including a possibly reduced risk of pressure sores and an improved metabolism. A more beneficial effect of hybrid training over upper-extremity training alone in decreasing the amount of trunk fat was not proven during this study. However, the individual changes in trunk fat mass pointed in the direction that was expected, and might become significant if the training period was extended or if more participants were included in the study. The current training period was probably too short and the frequency and current amplitude of the stimulation too low to find changes in BMD.

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Post-Exercise Hypotensive Responses Following a Single-Bout of Aquatic and Overground Treadmill Exercise in People Post-Stroke

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Abstract The purpose of this study is to investigate the effects of a single-bout of aquatic treadmill walking and overground treadmill walking on the magnitude and duration of post-exercise ambulatory BP in people post-stroke. The ambulatory BP of seven people post-stroke was monitored for up to nine hours after a bout of aquatic treadmill walking (ATW) and overground treadmill walking (OTW), performed on separate days. Mean systolic and diastolic BP values were compared between both exercise conditions and a day when no exercise was performed (control). Mean ambulatory systolic BP following ATW was reduced by 5% compared to the control day ($p < 0.01$) and displayed a systematic trend in reduced BP compared to OTW ($p = 0.051$). Mean ambulatory diastolic BP values following OTW and ATW were reduced by 6% and 7% respectively, compared to the control day ($p <0.01$). ATW demonstrated a reduction of 6% in mean systolic BP at the eighth hour of exercise compared to baseline ($p < 0.05$). This study demonstrated that people post-stroke are able to lower their BP, under free living conditions, for up to nine hours following a single bout of ATW. In addition, ATW may promote nighttime dipping of systolic BP and elicit a greater hypotensive response after exercise compared to OTW in people post-stroke.

Keywords stroke, exercise, blood pressure, treadmill.

Introduction

Recurrent strokes are a leading cause of death in individuals post-stroke and responsible for approximately one-fourth of all annual stroke cases in the United States (Go et al., 2013). While hypertension, blood pressure (BP) greater than 140 mmHg systolic and 90 mmHg diastolic, has been established as a key indicator of a first stroke occurrence, it has also recently been identified as a high risk factor for recurrent stroke (Arima et al., 2006; Brown, Lisabeth, Roychoudhury, Ye, & Morgenstern, 2005; Furie et al., 2011).

Prevention of hypertension after an acute stroke is the most effective approach to reduce the risk of recurrent stroke (Group, 2003; Patarroyo & Anderson, 2012). Although clinicians typically prescribe exercise solely as a long term-method of care for hypertension, a single bout of

exercise can facilitate an immediate reduction of BP that is clinically meaningful, otherwise known as post-exercise hypotension (PEH).

Treadmill exercise is a key facilitator of PEH (Gomes Anunciacao & Doederlein Polito, 2011) and has been reported to reduce post-exercise BP for durations ranging from seven to 24 hours *(Pescatello 1999;* (Terblanche & Millen, 2012). Aquatic treadmill walking (ATW) may provide clinicians with an alternative mode of exercise to manage hypertension in individuals post-stroke. Compared to overground treadmill walking (OTW), ATW has been reported to reduce post-exercise BP of healthy adult females in greater magnitude (Rodriguez et al., 2011). Unfortunately, no studies have examined post-exercise ambulatory BP in persons with stroke.

The purpose of this study is to investigate the effects of a single-bout of ATW and OTW on the magnitude and duration of post-exercise ambulatory BP in people post-stroke.

Methods

A total of 7 participants post-stroke were recruited for this study from a university-based aquatic therapy program. The mean age of participants in this study was 56.57 years (range: 36-67 years) and the average time post-stroke 4.85 years. All participants in this study were classified with normotensive levels of resting BP, and no participants were using anti-hypertensive medication throughout the study.

All participants completed 25 minutes of walking exercise on an aquatic and overground treadmill on two separate visits. Each visit participants completed a five-minute warm-up, 15-minute walking exercise at approximately 70% of peak oxygen consumption (VO2peak), and a five-minute cool-down. 70% of VO2peak was determined through the combined use of heart rate, real-time breath-by-breath analysis of oxygen consumption (VO_2) and Borg's rating of perceived exertion (Borg, 1982).

After completion of each walking trial, participants were equipped with an ambulatory BP monitor, and BP values were measured for a total of nine hours post-exercise. The first hour post-exercise consisted of seated rest in a controlled laboratory environment. Participants were then instructed to resume their daily activities for an additional eight hours while ambulatory BP was automatically recorded every 15 minutes. On a day prior to walking trials, participants measured their ambulatory BP on a day without exercise (control day).

Results

All seven participants completed the experimental procedures of this study. The test conditions did not show differences in pre-exercise resting BP.

The matched intensity of exercise between the two exercise conditions was determined based upon the average of breath-by-breath gas analysis of VO_2. Mean VO_2 values during the warm-up, exercise and cool-down were not significantly different between ATW and OTW.

Mean BP responses were compared between the pre-exercise baseline and the first, third, fifth, seventh, and ninth hour post-exercise. When compared to the aquatic pre-exercise baseline (115.0 ± 12.69), the ninth hour post-exercise demonstrated a reduction of 6% in mean systolic BP ($F_{(1,5)}$ = 12.78, p < 0.05). No other significant differences were found in mean systolic BP and diastolic BP among time phases within each test condition.

When comparing systolic BP at each time phase post-exercise between test conditions, significant differences were only found at the ninth hour. Mean systolic BP at the ninth hour following ATW was reduced by 11% ($F_{(1,5)}$ = 14.08, p < 0.01) compared to that of the control day

(122.5 ± 14.18). In addition, OTW displayed a trend of a 3% reduction of systolic BP at the same hour (118.35 ± 7.07) compared to that of the control day ($F_{(1,5)} = 5.82$, $p < 0.052$).

Following ATW, mean diastolic BP was reduced by 8% ($F_{(1,5)} = 12.73$, $p < 0.01$) at the ninth hour (70.86 ± 13.2) compared to mean diastolic BP of the control day (77.2 ± 11.1). Also, OTW showed a 7% reduction of mean diastolic BP at the ninth hour post-exercise (71.40 ± 9.21) compared to the control day ($F_{(1,5)} = 7.71$, $p < 0.01$).

In order to compare the mean BP response of the entire post-exercise period among conditions, BP values from each hour were averaged into a single overall value. This mean value was then compared between each condition. Overall post-exercise systolic BP following ATW was reduced by 3% compared to that of OTW ($t = 4.06$, $p < 0.05$) and 5% to that of the control day ($t = 5.11$, $p < 0.01$). OTW did not show a significant difference in overall systolic BP compared to the control day. On the other hand, mean overall post-exercise diastolic BP following both OTW and ATW was reduced by 6% ($t = 4.01$, $p < 0.01$) and 7% ($t = 4.33$, $p < 0.01$), respectively, compared to that of the control day.

Conclusion and discussion

Our findings suggest that systolic and diastolic BP may be reduced for up to nine hours following a single session of aquatic treadmill walking, compared to a day when no exercise is performed. Our results showed an overall decrease of approximately 6.3 mmHg systolic and 3.8 mmHg diastolic BP following aquatic treadmill exercise. These reductions appeared greatest during a later hour of the day. Overground treadmill exercise did not appear effective at reducing post-exercise systolic BP compared to a day without exercise but did demonstrate an overall reduction of diastolic post-exercise BP by approximately 3.2 mmHg.

People post-stroke have been found to lack a decline in BP at nighttime (Castilla-Guerra, Fernandez-Moreno Mdel, Espino-Montoro, & Lopez-Chozas, 2009; Jain, Namboodri, Kumari, & Prabhakar, 2004), which may cause an increased amount of strain on the internal organs of an individual. Our results were similar: on a day when no exercise was performed, people post-stroke displayed no decline in BP at nighttime when compared to morning BP values. However, after a person post-stroke exercised on an aquatic treadmill in the morning they were able to reduce their systolic BP by 6% at nighttime. This suggests that exercise on an aquatic treadmill may promote nighttime dipping of BP in people post-stroke.

Hypertension is the most important risk factor associated with recurrent stroke risk. The findings from this study demonstrated that people post-stroke are able to lower their BP, under free living conditions, for up to nine hours following a single bout of aquatic treadmill exercise. In addition, walking on an aquatic treadmill may promote nighttime dipping of systolic BP and elicit a greater hypotensive response after exercise compared to OTW in people post-stroke. Thus, ATW may be recommended for persons post-stroke who aim to lower their BP. Further investigation is necessary to verify whether these effects are translatable to people post-stroke with hypertension who use various and/or combined forms of pharmaceutical therapy.

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Physical Exercise, Stress, Burnout and Fatigue in Persons with Complete Spinal Cord Injury

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Abstract *Purpose:* Previous studies on physical exercise, stress, burnout and fatigue in persons with incomplete spinal cord injury demonstrated that physical exercise and degree of coping with disability-stress seemed to mediate the association between disability-stress and both burnout and fatigue. In addition, they experienced burnout and fatigue more frequently than the general population. In order to investigate if persons with complete SCI report similar results, a new questionnaire was sent to a sample of people with complete SCI. *Methods:* A total of 185 persons with SCI (AIS A), 147 males and 38 females, of which 62 persons with tetraplegia and 122 persons with paraplegia participated in a cross sectional survey. *Results:* The mean age was 51 (19 - 75) years and years' post-injury ranged between 2 and 54 years. The mean burnout score was 2.6 (SD = 1.0), and 10 persons, 6 % of those who completed the Pines burnout measure, scored above 4, the cut-off point for burnout. Mean score for fatigue severity scale was 3.8 (SD =1.3). Of the sample, 45 % scored 4 or above, whereas 15% scored 5 or above. Physical exercise was positively correlated with ability to maintain self-care (r= .234**, p<.01) and negatively correlated with fatigue (r = - .19, p<.05). *Conclusion:* The number of persons in the sample with motor complete SCI that experienced burnout and fatigue was similar to the general population and less than in a sample of persons with incomplete SCI. The participants were less physically active than the general population. A small positive correlation was found between physical activity and ability to maintain self-care, and a small negative correlation was found between physical activity and fatigue. No correlation was found between physical activity and disability related stress.

Keywords Spinal Cord Injury, Exercise, Stress, Burnout, Fatigue

Introduction

Being physically active is associated with improved physical fitness, health and psychological well-being in persons with Spinal Cord Injury (SCI). It has been estimated that only a small minority of healthy young persons with SCI have the minimal level of fitness needed to maintain independent living (Noreau & Shephard, 1995). Haskel, Blair & Hill (2009) reported that persons with physical disabilities are among the least active populations, and that they have more to gain from increasing the level of physical activity than the general population. Ditor et al. (2003) reported greater perceived quality of life and less stress and pain in individuals with SCI who participated in supervised exercise training two times a week than in a non-exercising cohort. Previous studies on physical exercise, stress, burnout and fatigue in persons with incomplete spinal cord injury demonstrated that physical exercise and degree of coping with disability-stress

seemed to mediate the association between disability-stress and both burnout and fatigue (Lannem 2011). In addition, persons with incomplete SCI experienced burnout and fatigue more frequently than the general population. In order to investigate the level of physical activity and if persons with complete SCI report similar results, a new questionnaire was sent to a sample of people with complete SCI.

Methods

The cognitive activation theory of stress (CATS) (Ursin & Eriksen 2004) was used as the theoretical framework in order to demonstrate how disability related stress affects persons with motor complete SCI.

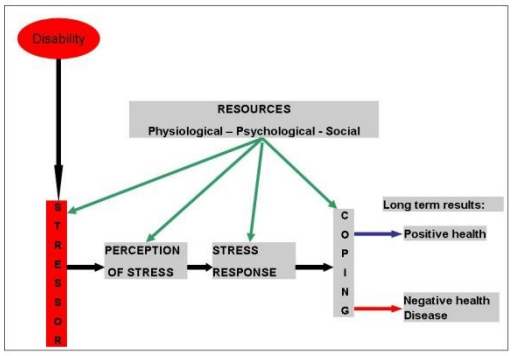

Figure 1. Illustration of CATS in relation to persons with SCI and physical exercise. The stressor is represented by the consequences of a SCI. The resources in all fields will influence how the stressor(s) are perceived in different situations, reaction to the stressor(s), as well as how the perceived stressor(s) are coped with (Lannem, 2011).

The design of the study was cross-sectional. Data was collected by a mailed questionnaire that measured perceived stress of the disability, leisure time physical activity, exercise mastery, coping, burnout and fatigue. Background information regarding injury level and severity, as well as additional injuries and complications, was collected by reviewing medical records. The AIS (ASIA impairment Scale) score A and B was used as the main inclusion criterion, and the injury level was divided into tetraplegia and paraplegia (Marino et al., 2003). All analyses were conducted using PASW statistics 18.0 for Windows (IBM, SPSS statistics, Norway). Descriptive statistics were used to characterise the sample. Data was summarised by mean values and standard deviations (SD) or median values and range, when appropriate. Independent sample t-tests were used to compare mean values of dependent and independent variables in tetraplegia versus paraplegia. Pearson's correlation coefficient was used for correlations between variables.

Results

The mean age was 51 (19 - 75) years and years' post-injury ranged between 2 and 54 years. The mean burnout score was 2.6 (SD = 1.0), and 10 persons, 6 % of those who completed the Pines burnout measure, scored above 4, the cut-off point for burnout. Mean score for fatigue severity scale was 3.8 (SD =1.3). Of the sample, 45 % scored 4 or above, whereas 15% scored 5 or above. Physical exercise was positively correlated with ability to maintain self-care ($r = .23$, $p<.01$) and negatively correlated with fatigue ($r = -.19$, $p<.05$).

Table 1. Mean scores and Pearson`s Correlations between variables

Variables	Mean	SD	1.	2.	3.	4.	5.	6.
1. PDSS	59.7	19.5	-					
2. LTPA	1.9	.9	-.054	-				
3. LiSat9, item 7	4.3	1.7	-.219**	.234**	-			
4. Coping	6.7	2.4	-.39**	.048	.059	-		
5. PBS	2.6	1.0	.553**	-.078	-.270**	-.467**	-	
6. FSS	3.8	1.3	.363**	-.187*	-.325**	-.262**	.553**	-

* Correlation is significant at 0.05 level (2-tailed), ** Correlation is significant at 0.01 level (2-tailed).
Abbreviations: PDSS: physical disability stress scale; LTPA: Leisure time physical activity; LiSat9: Life Satisfaction Scale, item 7, ability to maintain self-care; PBS: Pines burnout score; FSS: Fatigue severity scale

Conclusion and discussion

The study demonstrated that the number of persons in the sample with motor complete SCI that experienced burnout and fatigue was similar to the general population and less than in a sample of persons with incomplete SCI. The participants were less physically active than the general population. A small positive correlation was found between physical activity and ability to maintain self-care, and a small negative correlation was found between physical activity and fatigue. No correlation was found between physical activity or disability related stress.

Acknowledgements

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Feasibility of handcycle training during inpatient rehabilitation in persons with recent spinal cord injury

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Abstract The purpose of this study was to asses the feasibility of handcycle training during inpatient rehabilitation in persons with recent spinal cord injury (SCI). For this study, 45 persons with recent SCI participated in a structured handcycle interval training during the last 8 weeks of inpatient rehabilitation. Training was scheduled 3x/per week (24 sessions) and intended frequency was ≥2x/per week. Intended intensity was Borg scale 4 to 7 on a 10-point scale. Training details were registered by the trainer and an evaluation form was completed by participants. All except 4 participants completed the training. No adverse events were reported. Mean number of training sessions was 14.6±4.3 (range: 7-23), mean per week 1.8±0.3. Mean Borg score was 6.2±1.4. Training was enjoyed by 80% of participants. Common suggestions for improvement were starting training earlier in rehabilitation and increasing the training period. It can be concluded that the frequency of training was less than intended and that intensity of handcycle training was generally good or higher than intended. Furthermore, participants were mainly satisfied with the handcycle training.

Keywords Handcycle, training, rehabilitation, spinal cord injury

Introduction

Persons with recent spinal cord injury (SCI) are known to have low physical capacity (Haisma, Bussmann et al. 2006). A higher physical capacity has shown to be related to several health benefits, including a decreased risk of cardiovascular disease (De Groot, Dallmeijer et al. 2008). Handcycle training is known to be a successful method to improve physical capacity in persons with SCI (Valent, Dallmeijer et al. 2009). Therefore, handcycle training is suggested to be an important part of rehabilitation. However, handcycle training is not regular therapy in all rehabilitation centers in The Netherlands. Implementing a handcycle training into the rehabilitation program of this vulnerable group is possibly challenging. Therefore, the purpose of this study was to asses the feasibility of handcycle training during inpatient rehabilitation in persons with recent spinal cord injury (SCI).

Methods

Participants

This study is part of Act-Active, a longitudinal multi-center randomized controlled trial in which the added value of a behavioural focused intervention on physical behaviour, physical fitness and health is evaluated in persons with recent SCI. Persons were recruited from four Dutch rehabilitation centers: Rijndam in Rotterdam, Adelante in Hoensbroek, Heliomare in Wijk aan Zee and De Hoogstraat in Utrecht. Inclusion criteria were: SCI in initial inpatient rehabilitation, using a manual wheelchair and aged between 18 and 65 years.

Handcycle training

All participants performed a structured handcycle training program during the last eight weeks of inpatient rehabilitation. The training consisted of an interval training protocol on an add-on handcycle. Training was performed indoor by placing the handcycle in an ergotrainer or outside; depending on weather conditions and preferences of participants and trainers. The duration of each training session was 45 to 60 minutes including a short warming-up and cooling-down period.

Training was scheduled 3x/per week (24 sessions) and intended frequency was ≥2x/per week. Intended intensity was Borg scale 4 to 7 on a 10-point scale. Training details were registered by the trainer and an evaluation form was completed by participants

Results

A total of 45 persons were included; mean age 43±15 years, 87% men, 67% paraplegic and 64% with motor complete lesion. All except 4 participants completed the training; 2 had pressure ulcers, 1 was forced early discharge, and 1 disliked training. No adverse events were reported. Mean number of total training sessions was 14.6±4.3 (range: 7-23), mean per week 1.8±0.3. Mean Borg score was 6.2±1.4. Training frequency was less than intended in 50% of participants and intended training intensity was generally good (see Figure 1 and 2).

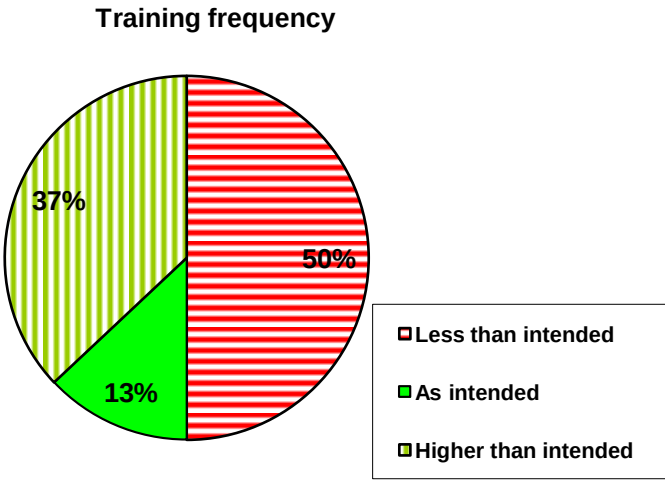

Figure 1.

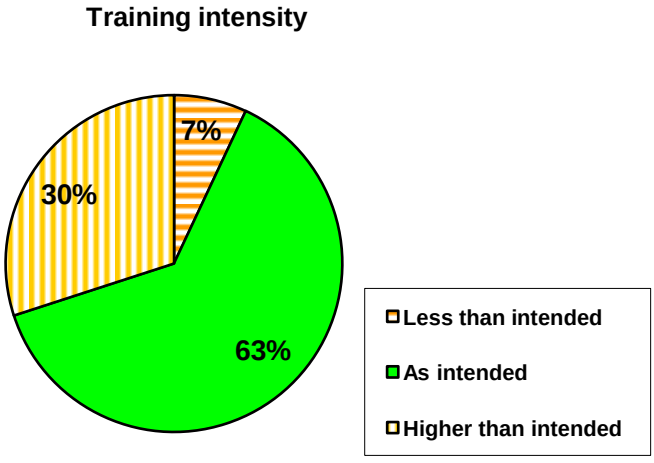

Figure 2.

Reasons for missed training sessions were other therapy/hospital visit (21%), discharge before end of training (16%), unavailability of trainer or material (12%), sickness participant (7%), holidays (5%), or unknown (39%).

Evaluation forms showed that training 80% of participants enjoyed training and that participants were mainly satisfied with training frequency (88%) and intensity (74%). Starting the training earlier in rehabilitation would have been preferred by 44% and a longer training period by 37% of participants.

Conclusion

Intensity of handcycle training was generally good or higher than intended. Frequency of training was less than intended; there seems to be room for improvement in planning and organisation of the training. Participants were mainly satisfied with the handcycle training. Common suggestions for improvement by participants were starting training earlier in rehabilitation and increasing the duration of the training period.

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Metabolic rate and cardiorespiratory response during hybrid cycling versus handcycling at equal subjective exercise intensity levels in people with a spinal cord injury

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Abstract: To compare the metabolic rate and cardiorespiratory response during hybrid cycling versus handcycling at equal subjective exercise intensity levels in people with spinal cord injury (SCI). *Design***:** Cross-sectional study. *Setting:* Amsterdam Rehabilitation Research Centre | Reade, Amsterdam, The Netherlands. *Methods:* On separate days, 9 individuals with motor complete paraplegia or tetraplegia (8men, age 40±13 years, time since injury 12±10 years) performed 5-minute bouts of hybrid cycling (day 1) and handcycling (day 2) at moderate (level 3 on a 10-point rating of perceived exertion (RPE) scale) and vigorous (RPE level 6) subjective exercise intensity, while respiratory gas exchange was measured by open-circuit spirometry and heart rate (HR) was monitored using radiotelemetry. Outcome measures were metabolic rate (calculated with the Weir equation) and cardiorespiratory response (HR, oxygen pulse (O_2pulse, and ventilation (V_E)). *Results:* Overall, the metabolic rate during hybrid cycling was 3.4 kJ (16%) higher (P=0.006) than during handcycling. Furthermore, compared with handcycling, the overall HR and V_E during hybrid cycling was 11 bpm (11%) and 5.3 l/minute (18%) higher (P=0.004 and 0.024), respectively, while the O_2pulse was statistically the same (P=0.26). *Conclusion:* Hybrid cycling induces a higher metabolic rate and cardiorespiratory response at equal RPE levels than handcycling, suggesting that hybrid cycling is more suitable for fighting obesity and increasing cardiorespiratory fitness in individuals with SCI.

Keywords: Exercise, Obesity, Physical fitness, Spinal cord injuries

Introduction

People with a spinal cord injury (SCI) are at risk to become overweight or obese due to their reduced physical activity levels as a result of their paralysis and subsequent wheelchair dependency (Monroe, Tataranni et al. 1998). To increase cardiorespiratory fitness and to fight obesity, individuals with SCI should exercise at sufficiently high metabolic rates. Exercise training in people with SCI often involves upper-body exercises, which may provoke a high subjective

intensity at relatively low metabolic rates due to the limited active muscle mass (Jacobs, 2009). Adding functional electrical stimulation (FES)-induced induced leg exercise to upper-body exercise (e.g. hybrid cycling) might be a way to increase the metabolic rate while exercising at the same subjective exercise intensity. The subjective exercise intensity can easily be assessed with a rating of perceived exertion (RPE) scale (Borg, 1982), and seemed to be an appropriate measure for exercise intensity during moderate to vigorous steady state exercise (Goosey-Tolfrey, Lenton et al. 2010). The aim of this study was to compare the metabolic rate and cardiorespiratory response during hybrid cycling versus handcycling at equal RPE levels in a group of individuals with SCI. It was hypothesized that, due to the larger muscle mass available, hybrid cycling would lead to a higher metabolic rate and cardiorespiratory response at equal RPE than handcycling.

Methods

Participants

Nine individuals with a motor complete paraplegia or tetraplegia participated in this study. Individuals with a spastic paralysis and absent or limited sense in the lower body were eligible to be included if they responded well (visible muscle contractions and no discomfort in the lower extremities) to FES for at least 5 consecutive minutes. They were excluded if they had contra-indications for physical testing, such as pressure sores, serious cardiovascular problems, or severe musculoskeletal complaints.

Protocol

Each measurement session consisted of a 2-minute warm-up and cool-down session of voluntary hand cycling in the specific test cycle (in case of the hybrid cycle this meant that the legs were moved passively). After the warm-up, the first 5-minute exercise bout was performed at moderate subjective exercise intensity (RPE level 3 on the Borg category ratio 10 (CR10) scale),12 and after a 5-minute rest interval, the second 5-minute exercise bout was performed at vigorous subjective exercise intensity (RPE level 6).

Outcome measures

Outcome measures were metabolic rate and cardiorespiratory response, defined as heart rate (HR), oxygen pulse (O_2pulse) and ventilation (V_E). Respiratory gas exchange (VO_2 and VCO_2) was measured using open-circuit spirometry (K4b², COSMED, Rome, Italy). The metabolic rate (kJ/minute) was calculated with the Weir method: $3.942 \times VO_2$ (l/minute)+VCO_2 (l/minute)×4.182 (McArdle, Katch et al. 2007), where VO_2 en VCO_2 were averaged over the last minute of the exercise bouts. The average HR (bpm) and V_E (l/minute) over the last minute of the bouts were used for analysis. O_2pulse (ml/beat) was calculated by dividing VO_2 (l/minute) by the HR (bpm).

Statistics

The effect of exercise modality (hybrid cycling, handcycling) and subjective exercise intensity (RPE level 3, RPE level 6) on the outcome measures was examined with two-way repeated-measure analysis of variance. If there was an interaction, paired t-tests were used to examine this interaction and to calculate the 95% confidence interval for each difference between the means.

Results

Metabolic rate

There was a significant main effect for both exercise modality ($F(1,8) = 13.55$, $p = 0.006$, $\eta p\ 2 = 0.63$) and exercise intensity ($F(1,8) = 23.73$, $P = 0.001$, $\eta p\ 2 = 0.75$). The difference in metabolic rate between hybrid cycling and handcycling (Fig. 1) was higher at RPE level 6 (4.4 kJ/minute (1.8, 7.0)) than at level 3 (2.5 kJ/minute (0.4, 4.5)). Furthermore, the difference in metabolic rate between RPE levels 3 and 6 was higher for hybrid cycling (7.7 kJ/minute (3.9, 11.4)) than for handcycling (5.8 kJ/minute (3, 8.5)).

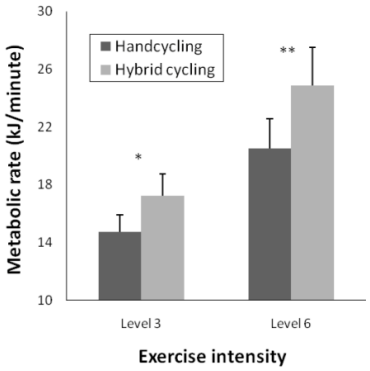

Figure 1. Metabolic rate (*p<0.05; **p<0.01)

Cardiorespiratory response

A significant main effect on the HR response was found for both exercise modality ($F(1,7) = 18.18$, $P = 0.004$, $\eta p\ 2 = 0.72$) and exercise intensity ($F(1,7) = 19.28$, $P = 0.003$, $\eta p\ 2 = 0.73$) (Fig.2A). The difference in HR (Fig. 2A) between hybrid cycling and handcycling was higher at RPE level 6 (17 bpm (7, 27)) than at level 3 (3 bpm (−6, 12)). Furthermore, the difference in HR between RPE levels 3 and 6 was higher for hybrid cycling (27 bpm (12, 41)) than for handcycling (15 bpm (7, 23)). There was a significant main effect for exercise intensity on the O2pulse ($F(1,7) = 15.96$, $P = 0.005$, $\eta p\ 2 = 0.70$) Fig. 2B). Overall, the mean O2pulse at RPE level 6 was 1.25 ml/beat (0.51, 1.99) higher than at level 3. No other effects were found. There was a significant main effect for both exercise modality ($F(1,8) = 7.77$, $P = 0.024$, $\eta p\ 2 = 0.49$) and exercise intensity ($F(1,8) = 65.22$, $P < 0.001$, $\eta p\ 2 = 0.89$) on the VE (Fig. 2C). The difference in VE between hybrid cycling and handcycling was higher at RPE level 6 (7.7 l/minute (2.6, 12.8)) than at level 3 (2.8 l/minute (−1.4, 6.9)). Furthermore, the difference in VE between RPE levels 3 and 6 was higher for hybrid cycling (15.5 l/minute (10.4, 20.5)) than for handcycling (10.5 l/minute (7.7, 13.3)).

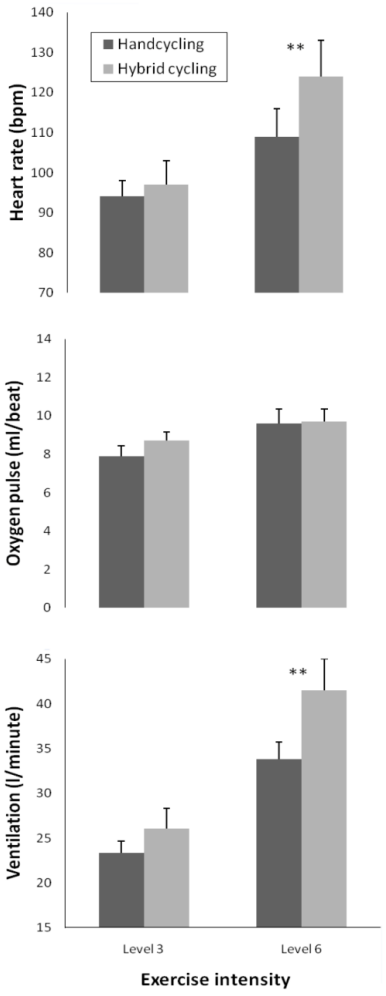

Figure 2. (A,B,C) Cardiorespiratory response (**p<0.01).

Conclusion and discussion

The metabolic rate and cardiorespiratory response during hybrid cycling were higher than during handcycling. Consequently, hybrid cycling might be more suitable for improving weight control and cardiorespiratory fitness.

Acknowledgements

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Evaluation of a 30min all-out and a 4-constant protocol to determine critical power for upper-body exercise

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Abstract The purpose of this study was to evaluate the estimate of critical power (CP) and work done above CP (W') in the upper extremities determined through both a 3-min all-out and a 4-constant protocol. The level of CP can be used to set training intensity and to reflect exercise capacity, in this study specifically in adaptive sports in which the upper extremities function dominantly. Twelve moderately-trained able-bodied adults (6 men) visited the laboratory at least six times, each time cycling on an arm crank ergometer. During the first visit, the participants performed an incremental test to exhaustion to determine maximal power output (POmax). Visit 2 consisted of a 3-min all-out protocol at a constant resistance (corresponding to 65% POmax), with CP defined as the average PO of the last 30s. Visits 3-6 consisted of 4 separate constant-power (70%, 80%, 90%, 100% POmax) tests until exhaustion (4-constant protocol) with CP defined as the asymptote of the PO-time-to-exhaustion curve. The CP and W' of the 3-min all-out protocol were 87±28 W (78% POmax) and 3.9±1.4 kJ, resp. The CP and W' of the 4-constant protocol were 71±19 W (64% POmax) and 7.4±3.4 kJ, resp. CP and W' of both protocols were significantly correlated (CP: 0.934; W': 0.706) but significantly different (both $P<0.001$), with increasing differences for high CP values. The relative CP of the 3-min all-out protocol (78%) is probably too high, supported by the fact that all participants maintained cranking for only ±8 minutes at 80% POmax during the 4-constant protocol. For the same reason, the relative level of CP determined through the 4-constant protocol could be accepted as a realistic value. It can be conclude that the 4-constant protocol gives different but more realistic values of CP than the 3-min all-out test, suggesting that this protocol should be used for determining upper-body CP.

Keywords Critical Power, upper body exercise

Introduction

Critical power (CP) is an important measure for the reflection of one's endurance capability, and the use of this level of power output as a training intensity distinguishes the heavy from the severy exercise (Poole et al., 1988). Physiologically, CP occurs at a similar intensity of a certain steady state of blood lactate accumulation (Pringle & Jones, 2002).

In 1981, CP of the legs was determined by the use of a cycle ergometer for the first time (Moritani et al., 1981). During this protocol, CP as well as the amount of work above CP (W') were successfully determined by series of tests to exhaustion each at a different but constant power output (PO). Vanhatalo et al. (2007) was the first to identify CP by using a 3-min all-out

test on the cycle ergometer. During this test the mainly anaerobic energy supply of W' decreased progressively until only the CP level could be attained (Burnley et al., 2006).

Since in adaptive sports upper body exercise is dominant, it is meaningful to be able to work and train with knowledge of CP also for this part of the body. The purpose of the present study is to develop and evaluate both a 3-min all-out protocol and a 4-constant protocol to estimate CP and W' for upper body exercise.

Methods

Twelve moderately-trained able-bodied adults (6 men) visited the laboratory at least six times, each time cycling on an arm crank ergometer. During the first visit, the participants performed an incremental test to exhaustion to determine maximal power output (POmax). Visit 2 consisted of a 3-min all-out protocol at a constant resistance (corresponding to 65% POmax), with CP defined as the average PO of the last 30s. Visits 3-6 consisted of 4 separate constant-power (70%, 80%, 90%, 100% POmax) tests until exhaustion (4-constant protocol) with CP defined as the asymptote of the PO-time-to-exhaustion curve.

Results

Mean values and standard deviations of the parameters POmax, CPs and W's are shown in table 1. CP and W' of both protocols were significantly correlated (CP: 0.934; W': 0.706) but significantly different (both $P<0.001$), with increasing differences for high CP values (figure 1).

Regression analysis between work and time to exhaustion showed for all participants a $R^2>0.988$. The relative CP of the 3-min all-out protocol (78%) is probably too high, supported by the fact that all participants maintained cranking for only ±8 minutes at 80% POmax during the 4-constant protocol. For the same reason, the relative level of CP determined through the 4-constant protocol could be accepted as a realistic value.

Table 1. Mean and standard deviations (SD) of POmax, CP, relative CP as a percentage of POmax and W' derived from the 3-min all-out test and the 4-constant test. * = significant difference between protocols ($P<0.001$).

	POmax (W)	CP (W)		Relative CP (%)		W' (kJ)	
	Incremental	3-min	4-constant	3-min	4-constant	3-min	4-constant
Mean	110	87	71*	78	64*	3.9	7.4*
SD	26	28	19	11	5	1.4	3.4

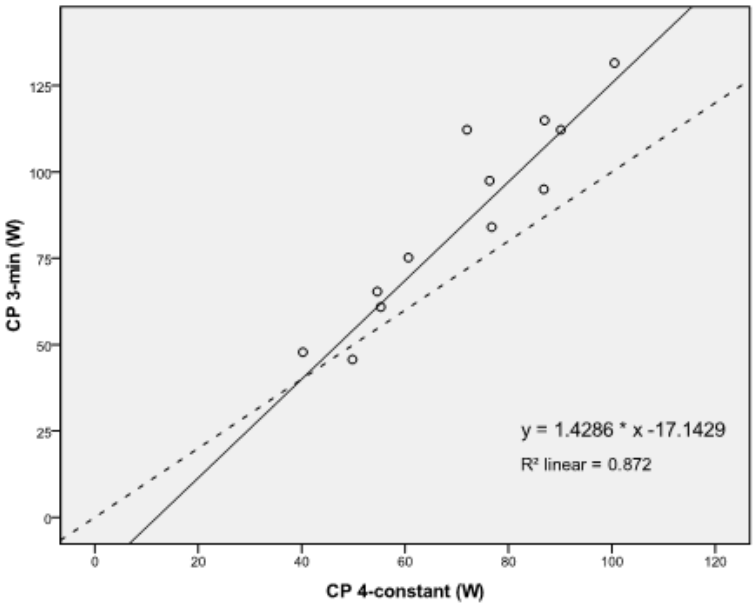

Figure 1. Relationship between CP 3-min and CP 4-constant. The solid line represents the measured relationship and the dotted line is the line of identity.

Conclusion

The 4-constant protocol gives different but more realistic values of CP than the 3-min all-out test, suggesting that this protocol should be used for determining upper-body CP.

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Effect of Uphill Treadmill Training on Walking Energy Cost in Stroke Patients: a Case Study

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Abstract. The main aim of the study was to evaluate the effects of an uphill treadmill training on walking energy cost in chronic stroke patients. Four patients (Age 53 ± 7 years; Weight 95 ± 15 kg; High 1.80 ± 0.10 m; BMI 29.6 ± 3.9; years of disease: 7 ± 2) were enrolled in the study. They performed three-month uphill treadmill interval training, three times per week, one hour each session. The subjects were evaluated before starting the training (T0) and after the end of the training (T1) by mean of: 6-minute walking test (6MWT), and three- speed walking energy cost test (C) and peak oxygen consumption (VO_2peak). The self- selected speed of the subjects was found by the 6MWT and the speeds used to perform the C test were 60%, 80% and 100% of self-selected speed (S-SS). The subjects performed an high intensity treadmill training. The mode of the training was uphill walking 4x4- minute intervals at 85% and 95% VO_2peak, preceded by 10-minute warm- up on the treadmill at their S-SS and 1% slope. Between the 4- minute intervals, 3- minute active recovery, approximately at 70% VO_2peak was applied. The training session was terminated by a 5- minute cool down period at 50% VO_2peak.

Keywords Uphill Treadmill Training, Walking Energy Cost, Chronic Stroke

Introduction

Cerebral stroke leads to disability, resulting in chronic neurologic deficits that persistently impair function in about two third of cases (Macko, Smith et al. 2001). Of the neurologic sequel that produce persistent functional disability, hemiparesis is the most common, with nearly half of all patients still affected longer than 6 months beyond the onset. Hemiparetic gait disturbances with associated weakness, spasticity, and abnormal central neural patterning of muscle activation markedly reduce the gross motor efficiency of ambulation. Individuals with chronic hemiparetic stroke gait deficit have 1.5 to 2 times the energy costs for ambulation, compared with controls whom are floor walking at the same velocity. Effort to minimize the impact and to improve functional outcomes after a stroke thus pose an important challenge for rehabilitation professionals. Gait restoration requires different techniques and often demands considerable assistance from the therapist to help the patient. The rehabilitation of stroke survivors is both expensive and demanding, and the results vary. The porpoise of the study was to investigate the effect of uphill treadmill training on walking energy cost in chronic stroke patients with hemiparesis.

Methods

Four chronic stroke subjects were recruited. The characteristics of the subjects are summarized in the Table 1. All the enrolled patients in the study were evaluated before starting the training (T0), and after the training (T1). The assessment protocol consisted in:

- Six Minute Walking Test (6MWT): subjects were required to walk a their self- selected speed for 6 minutes and the score was given by the covered distance (meters);
- Walking Energy Cost (C): breath by breath oxygen uptake was measured by using a metabolimeter (Cosmed, Quark b_2, Rome, Italy). The test was initiated asking the subjects t stand at rest for a period of two minutes. At the end of this period, the test commenced. Subjects walked on the treadmill performing three 3- minute steps. The speed of each step was determined by the self- selected speed of the subjects (obtained through 6MWT). The steps were 60%, 80% and 100% of their self- selected speed (S-SS) (Brazzelli, Saunders et al. 2012)
- *Peak of oxygen consumption (VO_2peak)*: breath by breath oxygen uptake was measured by using a metabolimeter (Cosmed, Quark b_2, Rome, Italy). Heart rate was measured using a Heart-rate monitor. The subjects were allowed to hold him/herself on the treadmill handrail with one hand. The test was stopped when the subject met the criteria given by the American College of Sport medicine. (Lam, Globas et al. 2010).

Table 1. Subject's characteristics

	Gender (M/F)	Age (years)	Type (IS/HE)	Paresis (R/L)	Weight (Kg)	Height (m)	BMI	Onset (years)	VO_2peak (ml/min/kg)
S1	Male	62	IS	R	107.5	1.78	33.9	7	14.1
S2	Male	55	IS	R	104.5	1.81	31.9	5	18.7
S3	Male	50	IS	L	95.5	1.92	25.9	1	30.1
S4	Male	60	IS	L	74.1	1.66	26.8	9	20.6
X	*4/0*	*56.8*	*4/0*	*2/2*	*95.4*	*1.79*	*29.6*	*5.5*	*20.9*
SD		*5.4*			*15.1*	*0.11*	*3.9*	*3.4*	*6.7*

The subjects performed a high intensity treadmill training. The mode of the training was uphill treadmill walking 4x4 mins intervals at 85% and 95% of VO_{2peak}, precede by 10- minute warm- up period on the treadmill at self- selected speed and 1% inclination. Between the 4- minute intervals, 3- minute active breaks walking at approximately 60% of VO_{2peak} was applied. The training session were terminated by a 5- minute cool-down period at 50% of VO_{2peak}.

Results

The distance covered during the 6MWT increased from a mean on 346.3 ± 165.0 to a mean of 266.0 ± 159.6 meters. Relative VO2peak increased from a mean of 20.9 ± 6.7 to a mean of 23.3 ± 7.5 (ml/min/kg) (Figure 2) . C (J*kg*m) at 60% of S-SS decreased from a mean of 4.57 ± 1.2 to a mean of 4.17 ± 1.4 (J*kg*m). C (J*kg*m) at 80% of S-SS decreased from a mean of 4.10 ± 2.0

to a mean of 3.93 ± 1.5 (J*kg*m). C (J*kg*m) at 1000% of S-SS decreased from a mean of 4.55 ± 1.4 to a mean of 2.94 ± 1.5 (J*kg*m) (Figure 1).

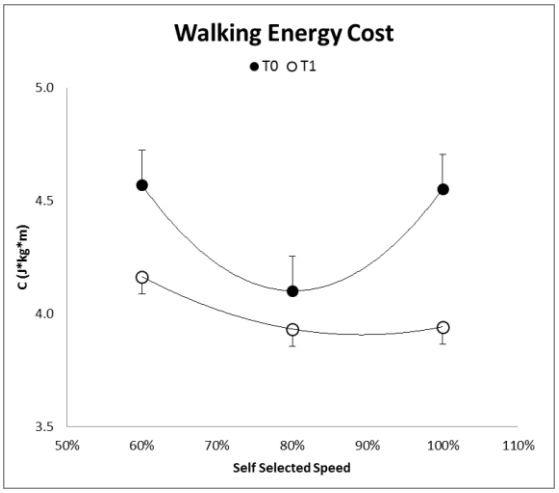

Figure 1. Value of C (J*kg*m) for each speed: 60%, 80% and 80% of S-SS

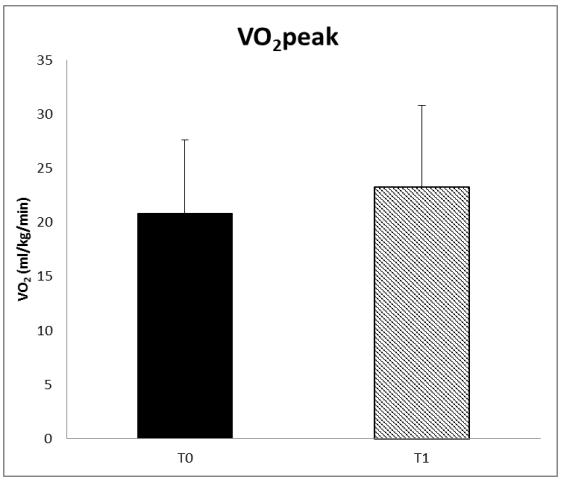

Figure 2. Value of VO2peak pre and post- training

Conclusion and discussion

The results show how uphill treadmill training lead to improvements in both, cardiorespiratory fitness and walking energy cost in chronic stroke patients. C (J*kg*m) decreased more at the 100% of S-SS in all the four subjects. This improvement could be given by a change or an adaptation in the gait kinetic. The adaptation in the gait kinetic would allow hemiparetic subject to improve the economy of walking. When the economy of walking improves the subjects expends less energy per unit distance walked and the effort is reduced.

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Exercise capacity after sildenafil ingestion in athletes with spinal cord injury

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Abstract *Purpose:* The ingestion of sildenafil citrate was found to have some performance enhancing effects at high altitudes above 3800m in able-bodied subjects. However, it is unknown whether sildenafil citrate can improve the performance of spinal cord injured athletes at moderate altitudes (<2200m), relevant to Paralympic competitions. As most men with a spinal cord injury suffer from erectile dysfunction of neurologic origin and use sildenafil on a regular basis it seems important to study the impact of sildenafil on exercise capacity, especially in view of the increasing interest of the anti-doping community in this substance class. *Methods:* 27 healthy male wheelchair athletes with a motor complete spinal cord injury participated in this prospective double-blind, placebo-controlled, randomized study. They performed arm cranking exercise to exhaustion at sea level and moderate altitude (2200m) after ingestion of 50mg sildenafil citrate or placebo. Peak power output, peak oxygen uptake, peak heart rate, rating of perceived exertion, oxygen saturation and lactate concentrations at exhaustion were measured. *Results:* A Friedman analysis showed that peak power output at sea level was found to be significantly higher (p=0.004) under placebo treatment (median [min; max] 120W [35; 170]) compared to sildenafil (115W [40; 165]). Blood oxygen saturation under sildenafil treatment at sea level (98% [81;100]) was significantly higher (p=0.006) compared to sildenafil treatment at moderate altitude (94% [85;100]). All other parameters showed no impact of sildenafil or altitude. *Conclusions:* In our study, the ingestion of sildenafil citrate in athletes with spinal cord injury showed no positive effects on peak arm cranking exercise capacity compared to placebo neither at sea level nor at moderate altitude.

Analyzing 3D biomechanics of disabled golf athletes; development and validation of a custom made model

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Abstract One of the prerequisites of the International Paralympic Committee states that Paralympic sports should have an evidence based classification system. To properly classify disabled golf athletes, a full understanding of the biomechanics during golf is necessary (Stoter et al. submitted 2014). Little is known about the relation between impairments and golf performance. Although various golf models to analyze able-bodied golf athletes exist (Betzler et al, 2008; Demerican, 2012), to the knowledge of the authors, no such model is capable of analyzing golf biomechanics in relation to impairments. To investigate the consequences of the level of a lower limb amputation, a custom made inverse dynamics OpenSim model (3D, 16 segment, 40 Degrees of Freedom) is developed. This model can be used to investigate the biomechanical differences at the joint level (net moments) due to the level of amputation and the consequences for the golf swing. Prior to investigating these issues, the custom made model must be tested and validated. The first step in validating the custom model consists of analyzing a golf swing of able-bodied subjects. The outcome parameters of the custom model will be compared to the predictions of existing able-bodied golf models.

Keywords Disabled golf, handigolf, biomechanics, amputation, develop, custom model, OpenSim

Introduction

One of the prerequisites of the International Paralympic Committee (IPC) states that Paralympic sports should have an evidence based classification system (IPC 2007). The challenges and questions that need to be addressed to develop an evidence based classification system for golf in accordance with IPC regulations have been identified in a review (Stoter et al. submitted 2014). Adjacent, Stoter et al. concluded that timing, accuracy and control, work per joint, range of motion, balance and flexibility are sport specific factors that determine performance in golf. Furthermore, the need to understand the biomechanics involved in handigolf was expressed. To gain insight in the biomechanics of handigolf, a custom made inverse dynamic OpenSim model (3D, 16 segment, 40 Degrees of Freedom) is being developed. OpenSim is free open-source software, developed at Stanford University (Delp et al. 2007).

Methods

The approach to modeling of Dym was followed during development (Dym 2006). According to Dym, there are a few questions to be answered prior to developing a model (Fig. 1). These questions are addressed below.

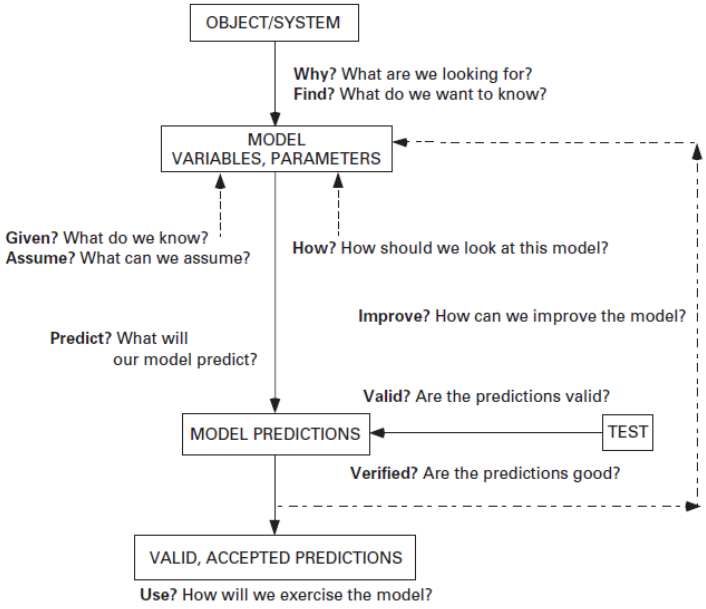

Figure 3. Schematic of Dym's approach to modeling (Dym 2006, p. 7)

Why: Very little is known about the relation between impairments and golf performance. Although various golf models to analyze able-bodied golf athletes exist (Betzler et al., 2008; Demerican 2012), to the knowledge of the authors, no such model is capable of analyzing golf biomechanics in relation to impairments. *Find*: Insight in the biomechanics of handigolf should lead to a quantifiable measure, which operationalizes the extent of activity limitation due to impairment when executing a golf swing. *Given*: Segment properties such as length, mass and range of motion are based on anthropometric data (Dirken 2001, Zatsiorski 2002). The equations of motion are solved by a Featherstone algorithm. *Assume*: It is assumed that segments are made of rigid bodies. The foot and forearm-hand combination have been simplified to a single rigid body. The knee joint is represented by a hinge joint. *How*: Since the model represents the biomechanical system of the human body, physics laws motion and laws of conservation should apply. *Predict*: The inverse dynamics model will be able to predict joint forces, moments and joint angles based on ground reaction forces and motion capture data. *Valid*: Calculations will confirm whether the laws of conservation apply to the model. In addition, the simulated movements of the segments should be physically possible. *Verified*: Kinetic and inverse dynamic predictions of our custom model will be compared with existing models. Model outputs are expected to be similar. *Improve*: An iterative loop will be implemented after testing the model for the validity and quality of its predictions (Dym 2006). This loop consists of remodeling, testing, improving and predicting the outcome of the model till the quality and validity of the predictions are satisfactory. Continued development of the model will allow conducting forward dynamic simulations as well. *Use*: This model will be used to investigate the biomechanical differences at the joint level (net moments) due to the level of amputation and its consequences for the execution of a golf swing. The acquired insights of handigolf biomechanics will contribute to the development of a classification system for handigolf.

Preliminary results and future issues

Our model will be tested, validated and refined, prior to investigating how a lower limb amputation affects the biomechanics of the golf swing. Visit www.handigolf.info to see our latest progress.

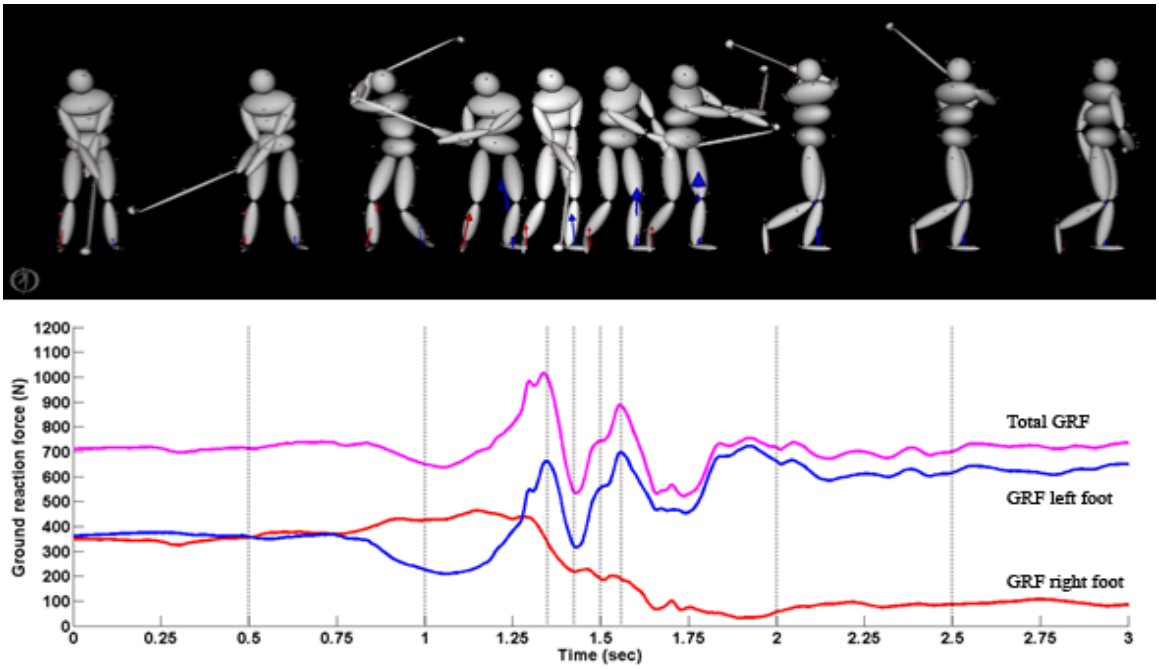

Figure 4. Preliminary results of model kinematics and measured ground reaction forces (GRF) of an able-bodied recreational golf player.

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Discussion about different effects of a rocker bar during running

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Abstract *Purpose:* To investigate the effects of a rocker profile shoe during running. Three different trials. 1) moments, power and EMG during slow running in healthy runners. 2) the same in patients with Achilles tendinopathy and 3) foot pressure and oxygen consumption in healthy female running on a treadmill and a 22 m runway. All studies are part of the dissertation of Sobhan Sobhani: „Rocker shoes for ankle and foot overuse injuries: a biomechanics and physiological evaluation". The results of the different trials cannot be pouled. However, in the same and in different trials results look conflicting.The purpose of this presentation is a discussion about the conflicting results in these trials. *Methods:* For used devices and data processing we refer to the mentioned dissertation.1) 16 experienced healthy runners; running 7 k/h; cross-over design with random order of shoes. 2)13 patients with Achilles tendinopathy, objectified with ultrasound, for at least 3 months; slow running; cross-over design with random order of shoes. 3)18 healthy endurance female runners; running + 11 k/h; cross-over design with random order of shoes. *Results/Discussion:* With a rocker profile the max plantar flexion moment, moment impulse and ankle power generation decreased. The knee- and hip moments did not change. People walked with the same speed. Oxygen consumption with rocker profile shoes was 4.5% higher. How to combine the same speed with the decrease of the power generation and higher oxygen consumption? The peak emg of the Medial/lateral Gastrocnemius and Soleus did not change. How to combine this with the decrease of the plantar flexion moment and the decrease of the ankle power generation? The pressure under the forefoot decreased and the pressure under the heel increased. How can a rocker profile influence the pressure under the heel? These questions will be addressed during the presentation.

Continuous kinematic gait analysis during a marathon to objectify the influence of fatigue; first results

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Abstract *Purpose:* Running is associated with high incidence of running related injuries. Fatigue can be considered to be an important factor in the development of these injuries, although its exact influence is not fully understood. Studying the influence of fatigue is difficult in the lab setting but recent developments in sensor technology allow continuous 3-d kinematic analysis of running technique outside the lab. This study was a first step towards objectifying the influence of fatigue on the running technique in the sport specific setting of an actual marathon. *Methods:* One trained male runner was equipped with 8 wireless inertial 9 degrees of freedom motion sensors (containing an accelerometer-, magnetometer and, gyroscope) on the feet, lower and upper legs, sacrum and sternum. Data was gathered throughout the 42,2 km of the Enschede Marathon and transmitted wirelessly to a tablet pc carried by an accompanying cyclist. Fatigue was expressed as the ratio between Heart Rate (HR) and velocity. Raw sensor data was processed and segment calibration was performed off line. At three stages during the marathon, where the runner was running on level ground in a straight direction, hip, knee and ankle angles, stride length and step frequency were calculated. Joint angles were normalized to cycle length and averaged over 200 gait cycles per stage. *Results:* Fatigue increased during the marathon as the ratio between HR and velocity increased. Step frequency remained constant while stride length decreased from an initial 2.59 meters to 2.15 meters per stride. Ankle plantar flexion and knee peak flexion decreased during (mid-) swing and ankle plantar flexion decreased at toe-off. *Conclusion:* This pilot study showed the possibility of performing a continuous 3-d kinematic analysis of the running technique during an actual marathon and of objectifying the influence of fatigue on this technique.

Keywords: Running mechanics, kinematics, gait analysis, fatigue

Introduction

Running is a popular sport that is characterized by a high incidence of running related injuries (van Gent et al. 2007). Etiology of running related injuries is believed to be multifactorial but still not fully understood (Hreljac, 2005; Van der Worp et al. 2012). Fatigue is considered to be an important underlying factor in the development of these injuries (Clansey et al. 2012). The influence of fatigue on running mechanics is complex and differs between individuals based on the level, type and experience level of subjects. Central and peripheral fatigue might cause changes in the body's ability to effectively maintain consistent movement patterns. Most studies on the influence of fatigue on running mechanics have been performed within the limitation of a controlled laboratory setting on walk-ways and on (instrumented) treadmills. Recent

developments in wearable and wireless sensor technology allow continuous three dimensional kinematic analysis of running technique outside the lab in the sport specific situation. Aim of the present study was therefore to investigate the possibility of performing a continuous 3D kinematic analysis of the running technique during an actual marathon and to objectify the influence of fatigue on running mechanics during a marathon in a single subject study design.

Methods

Four runners were participated in this experiment. Data is reported for one runner. This was an experienced and healthy male runner (31 yrs, 78 kg, 182 cm, average weekly distance run 45 km). The runner was equipped with 8 wireless inertial motion units (IMU) (Xsens MTW ce, Xsens Technologies B.V., Enschede, the Netherlands). The IMU's contain an accelerometer, gyroscope and magnetometer and are able to measure motion with 9 degrees of freedom. IMU's were placed on the feet lower and upper legs, sacrum and sternum. Sensor data was gathered, with an internal sample frequency of 1800 Hz throughout the 42.2 kilometer (26.2 Miles) of the Marathon. Dynamic calibration trials were performed before and after the marathon in order to perform a segment calibration. Data was collected continuously and transmitted wirelessly with an update rate of 60 Hz to a tablet pc, mounted on the bicycle of an accompanying cyclist. HR was measured throughout the event while velocity was continuously derived from GPS measurement. Fatigue was expressed as the ratio between HR and velocity throughout the event. Three stages were defined during the marathon where the runner was running in a straight line on level ground. These stages started at 13.5, 33.9 and 39.0 kilometer. Raw sensor data was processed off line into 3D segment orientation. Joint angles (of the hip, knee and ankle) and stride length (the distance in meters between two consecutive initial foot contacts of a single foot) and step frequency (the frequency of steps, consequent feet contacts) were calculated. Joint angles were normalized to cycle length and averaged over 200 gait cycles per stage.

Results

Fatigue increased throughout the marathon. Stride length decreased with 45 cm from 2.61 meters to 2.15 meter while stride frequency remained constant. No trend could be witnessed in changes in hip angle between the three stages. Max knee flexion during swing decreased with in total 14 degrees from 103 degrees (stage 1) to 97 degrees (stage 2) to 89 degrees (stage 3), while mininum values increased from -7 to -5 degrees of flexion from stage 1 to stage 3. Max ankle plantar-flexion at push off decreased with 11 degrees from -37 degrees (stage 1) to -32 degrees (stage 2) to -26 degrees (stage 3). During midswing plantar-flexion decreased between stage 2 and 3 from 23 to 12 degrees.

Conclusion and discussion

To our knowledge, this is the first study that actually measured 3d kinematics continuously outside the laboratory in the sport specific setting of running. This study showed the possibility of performing a 3d kinematic analysis of the running technique, in the sport specific setting, by using inertial sensors. For this single runner, the effects of fatigue on running mechanics were objectified were differences were observed in stride length and for ankle angle at push off and

during swing and for knee angle during swing. The present measurement technique allows for more in-depth study of the effects of fatigue on running mechanics. Future studies need to include more runners in order to investigate the assumed inter-individual different responses to fatigue and link these in a retrospective or prospective design to running related injuries.

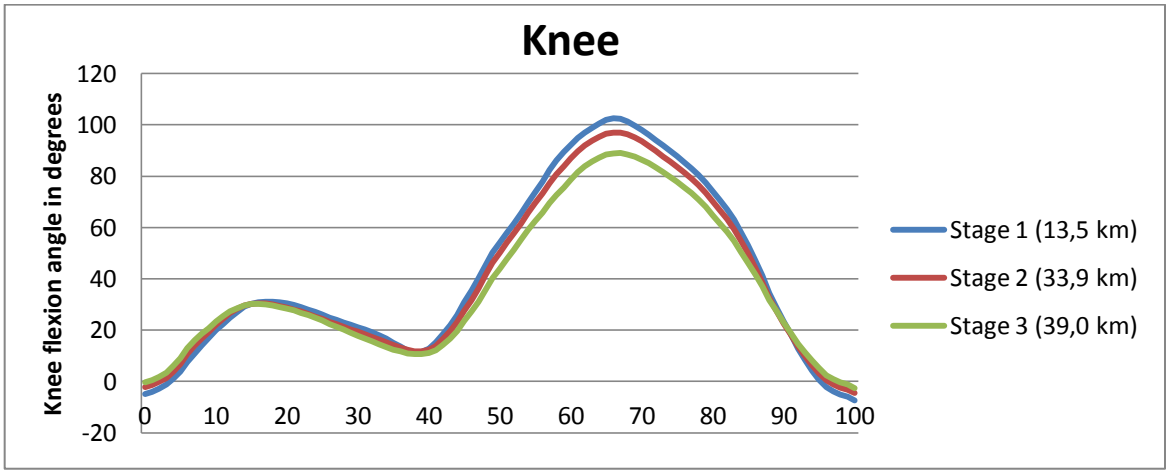

Figure 2: Right knee flexion during stride cycle (averaged over 200 strides)

Table 1: Spatiotemporal parameters

	Stage1	Stage2	Stage3
Distance	13,5	33,9	39,0
Distance covered for 200 strides (meters)	525,8	464,4	432,1
MeanVelocity (km/h)	13,5	12,0	11,2
Stride Duration_M (seconds)	0,69	0,69	0,69
Stride Length_M (meters)	2,61	2,31	2,15
Step Frequency (steps per minute)	173	174	173
Heart Rate (BPM)	148	158	155
Fatigue ratio	10.9	13.1	13.8

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Figure 2. Experimental set up during the Marathon

Non-surgical treatment of non-specific chronic wrist pain: a systematic review

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Abstract *Purpose:* To systematically review the evidence for the effectiveness of non-surgical treatment in reducing pain and restoring activity and participation level in patients with non-specific chronic wrist pain. *Methods:* A systematic literature search was performed in Pubmed, Embase, Cochrane, CINAHL and PsychINFO^{R}. Studies included were randomized controlled trials (RCTs), case-control studies, case series (with at least five patients), meta-analyses, which assessed a non-surgical treatment of chronic wrist pain in adult patients. Two reviewers independently checked the search results against the inclusion and exclusion criteria: the methodological quality and the hierarchy of evidence in levels were classified. *Results:* A total of 7273 studies were screened for eligibility. Three studies (RCTs) were eventually included. All three articles described pain reduction as a primary outcome and two described outcomes on activity levels. No evidence was found for the effectiveness of any treatment in the RCTs. Improvement in pain scores was found after treatment in one study in both the treatment and control groups. *Conclusions:* Little research of acceptable methodological quality has been performed after treatment for non-specific chronic wrist pain. No evidence for the effectiveness of non-surgical treatment on non-specific chronic wrist pain and activity or participation levels was found.

The Psychosocial Impact of Wheelchair Tennis on Participants in Developing Countries

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Abstract Individuals with physical disabilities in developing countries endure significant psychological hardship and poor quality of life. Although scholars have suggested a link between participation in sport and improved psychosocial health, few studies have demonstrated this relationship in developing nations. For this study, seventeen wheelchair tennis players were recruited across six developing countries and were interviewed in regards to their experiences. Interviews were transcribed verbatim and the data subject to thematic analysis. Three superordinate themes were identified; improved psychological well-being, improved social well-being and barriers to well-being. Psychologically, wheelchair tennis improved self-perceptions, subjective well-being and increased life opportunities. Socially, participation in wheelchair tennis improved perceived social support, increased players' socializing and developed knowledge sharing opportunities. These psychosocial benefits, however, were tempered by external (lack of tangible support and awareness) and internal (psychological pressures) barriers. It was concluded that wheelchair tennis significantly enhanced psychosocial well-being and quality of life of disabled people in developing countries, but that more must be done to overcome barriers to participation.

Keywords psychosocial, wheelchair tennis, developing countries

Introduction

Individuals with disabilities in developing countries face significant psychological and social hardship including poor mental health and isolation from society (Mitra, S., Posorac, A., & Vick, B, 2012; Livneh, 2012). Research has found sport to be an effective tool in alleviating these stresses (Kay, Dudfield and Kay, 2012). Very little research, however, has focused on the potential impact of wheelchair tennis. Furthermore, this potential impact has not been investigated using participants from a range of playing levels nor from countries out-with South Africa. The aim of this study was to address this gap by investigating how participation in wheelchair tennis improved psychosocial well-being and quality of life for disabled individuals in developing countries.

Methods

Participants

Seventeen participants from six countries were interviewed regarding their experiences of wheelchair tennis and how this impacted their overall quality of life. All participants were affiliated with the Wheelchair Tennis Development Fund (WTDF), an intervention initiative providing sustainable wheelchair tennis programs in developing countries. Participants' playing level ranged from development to elite.

Data Collection

Data collection was conducted using sixteen face to face, semi-structured interviews and one e-mail interview. Interviews were carried out by the first and second authors who conducted eleven and six interviews respectively. Fourteen participants were interviewed at a development tournament in Turkey and two at a British wheelchair tennis event.

Data Analysis

All interviews were transcribed verbatim and analyzed using thematic analysis as described in Braun and Clark's (2006) 6 stage guide. This allowed the researchers to identify common themes of interest. After immersing themselves in the data, researchers generated initial codes by highlighting data extracts which were of interest. These codes were then sorted and collated into similar themes. These themes were then reviewed to see if they could be broken down further or merged together. Following this, themes were defined and named. Finally, an academic report was produced describing and analyzing the results.

Results

Three superordinate themes were identified; improved psychological well-being, improved social well-being and potential barriers to well-being. Psychologically, participants found that participation in wheelchair tennis improved their self-perceptions, subjective well-being and increased their life opportunities. Socially, perceived social support, increased social life and developed knowledge sharing opportunities were enhanced through taking part in this sport. Despite these psychosocial benefits however, there were external and internal barriers which tempered these affects. Participants reported a lack of tangible support, lack of awareness of wheelchair tennis and psychological pressure to perform as barriers which could potentially hinder future development of the sport.

Conclusion and discussion

Participants perceived wheelchair tennis to have a positive impact on their psychosocial well-being and quality of life. It was concluded that taking part in this sport had a positive impact in other life domains, such as family and education, as well as within their sporting sphere. This significantly contributed to feelings of enhancement in overall quality of life. Despite the positive impact of this sport, without future financial and psychological support and raising awareness of wheelchair tennis, these benefits will only be experienced by a small sample of this population.

Acknowledgements

We would like to thank the WTDF for allowing us to attend tournaments and their continued support throughout the research process.

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Attitudes of people with disabilities (hearing impaired, visually impaired, speech disorders and mobility disorders) in the KSA about participating in recreational sport activities

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Abstract The number of people with special needs has increased lately in KSA (Ministry of Economy & Planning, 2007). People with disabilities are an important group of people who contribute equally to life in this modern world. Therefore, they should be accorded the same rights as everyone else to live happily, without any discrimination from the other segments of society. A change in the perception of people with disabilities in KSA can greatly help to develop the local Arab community and encourage people with disabilities to play a more active and productive role in society. The purpose of this study was to examine the attitudes of people with disabilities (hearing impaired, visually impaired, speech disorders, and mobility disorders) in the KSA about participating in recreational sport activities. *Methods:* The data was collected from randomly selected People with disabilities in KSA and the study used a cross-sectional survey using a validated self-administered questionnaire. Questionnaire was delivered to the all People with disabilities (hearing impaired, visually impaired, speech disorders, and mobility disorders) (N = 504) in five selected cities of KSA (Al-Riyadh, Makkah, Eastern Region, Jazan and Al-Jouf). *Results:* The results of this study indicated that people with disabilities have slightly high attitudes towards participating in sport and recreational activities.

Keywords Attitudes, People with Disabilities, Sport and recreational activities, Participation, Saudi Arabia.

Introduction

Attitude may be one of the most difficult obstacles that individuals with disabilities encounter in their participation in sports and recreational activities (Bedini, 2000; Schleien, Ray, & Green, 1997; Smith, Austin, Kennedy, Lee, & Hutchison, 2005). As Bedini (1992) stated, “People with disabilities historically have experienced distinction and devaluation based exclusively on being different from the non-disabled people” (p. 45). The purpose of this study was to examine the attitudes of people with disabilities (hearing impaired, visually impaired, speech disorders, and mobility disorders) in the KSA about participating in recreational sport activities.

Methods

The data was collected from randomly selected People with disabilities in KSA and the study used a cross-sectional survey using a validated self-administered questionnaire. A questionnaire was delivered to the all People with disabilities (hearing impaired, visually impaired, speech disorders, and mobility disorders) (N = 504) in five selected cities of KSA (Al-Riyadh, Makkah, Eastern Region, Jason and Al-Jouf).

Results

The attitude was measured using a five-point Likert scale with 1 as “strongly agree” and 5 as “strongly disagree.” All 504 participants responded to all items. The average response was around 3 with a standard deviation of around 1.41.

Table 1.1 shows that the most common item that the respondents rated low is Item 12. For Item 12 (“Recreational sport programs do not attract me to participate”), 59 percent of respondents either strongly agreed or agreed (*M* = 2.36, *SD* = 1.26). The most common item that the respondents answered highly is Item 5. As for Item 5 (“I do not feel happy when I participate in recreational sport activities”), 53.8 percent of respondents either strongly disagreed or disagreed (*M* = 3.30, *SD* = 1.41), as shown in Table 1.1 The overall results indicate that people with disabilities have a slightly high attitudes toward participating in sport and recreational activities (*M* = 2.90 and *SD* = 1.418).

Table 1.1 Mean (M) and standard deviations (SD) of the Attitude towards participation in recreational sport activities (N=504)

Attitude questions	1 SA* No. (%)	2 A* No. (%)	3 N* No. (%)	4 D* No. (%)	5 SD* No. (%)	*M*	*SD*
12) Recreational sport programs do not attract me to participate.	168 (33.3)	131 (26)	92 (18.3)	81 (16.1)	32 (6.3)	2.36	1.266
2) I am not knowledgeable in the technical use of sports equipment.	149 (29.6)	154 (30.6)	92 (18.3)	70 (13.9)	39 (7.7)	2.40	1.255
1) I feel exhausted after participating in sport activities.	124 (24.6)	167 (33.1)	103 (20.4)	73 (14.5)	37 (7.3)	2.47	1.214
6) I have a weak motive to participate in recreational sport activities.	116 (23)	106 (21)	92 (18.3)	113 (22.4)	77 (15.3)	2.86	1.397
8) My family has negative attitude towards s recreational sport activities.	123 (24.4)	90 (17.9)	84 (16.7)	131 (26)	76 (15.1)	2.89	1.418
11) Customs and social traditions embarrass me when participating in recreational sport activities.	117 (23.2)	100 (19.8)	91 (18.1)	109 (21.6)	87 (17.3)	2.90	1.424

7) I am not confident in myself and in my ability to participate in recreational sport activities.	112 (22.2)	83 (16.5)	104 (20.6)	107 (21.2)	98 (19.4)	2.99	1.431
10) I feel worried and unstable while participating in recreational sport activities.	97 (19.2)	92 (18.3)	86 (17.1)	110 (21.8)	119 (23.6)	3.12	1.451
9) I feel embarrassed wearing sport clothes in front of others.	119 (23.6)	77 (15.3)	58 (11.5)	111 (22)	139 (27.6)	3.15	1.550
4) I do not have the desire to participate in recreational sport activities.	76 (15.1)	110 (21.8)	73 (14.5)	146 (29)	99 (19.6)	3.16	1.369
3) I do not find recreational sport activities useful.	89 (17.7)	80 (15.9)	77 (15.3)	159 (31.5)	99 (19.6)	3.20	1.390
5) I do not feel happy when I participate in recreational sport activities.	86 (17.1)	71 (14.1)	76 (15.1)	150 (29.8)	121 (24)	3.30	1.413
overall	1376 (22.8)	1261 (20.8)	1028 (17.0)	1360 (22.5)	1023 (16.9)	2.90	1.418

**SD=strongly disagree, D=disagree, N=neutral, A=agree, SA=strongly agree*

Conclusion and discussion

The attitude of people with disabilities can encourage or discourage their interest to participate in communities. The findings of this study indicated that people with disability have a slightly high attitude toward participating in recreational sports with a mean of 2.90 (SD = 1.418). Disabled participants faced different obstacles that diminished this attitude. The results show that attitude can be negatively affected by psychological states such as exhaustion, low motivation, lack of support from family and friends, low confidence, and anxiety. These obstacles, according to Rimmer et al. (2004), make disabled people feel less safe, stressed out, anxious, lacking in motivation and confidence, and poorly socialized. Moreover, disabled people feel fatigued and lack knowledge about their own competence. A diminished attitude could be the result of interpersonal constraints arising from limited interaction with others (family and friends) and lack of social support. Crawford, Jackson, and Godbey (1991) mentioned constraints arising from external conditions as well as factors such as time, money, transportation, and appropriate equipment. Society could encourage a positive attitude among disabled people to participate in recreational sports activities. However, the interviews with disabled people revealed that society obviously does not effectively play its supposed role. They express their frustration toward their communities, which only merged disabled people with able-bodied ones in schools and universities rather than in all community facilities. Engaging disabled people in all social activities accordingly increase their positive attitude toward participation in recreational sports activities. According to the findings of this study, the attitude of disabled people could be an indication of the modest attitude of society toward participating in recreational sport activities in general. Thus, Saudi society has less engagement in physical activities compared with Western society, and has a low attitude toward recreational sports activities for disabled people as well as for able-bodied ones.

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Visual strategies during walk through an obstacle course: a comparison between young and elderly

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Abstract The purpose of this study was to determine whether elderly people without visual problems visually sample the environment in a different way than young people do, when walking an unfamiliar route with obstacles. Twenty six healthy adults, with a visual acuity >5/10 were asked to move through an obstacle course with 4.91m length and reach a pre-defined exit location. Twelve cones were used as obstacles to be avoided during the walk-through. Participants were divided into two groups (Young N=14; M=20.6 (±1.6); Elderly, N=12; M=71 (±3.2)). Their gaze (location, and duration of fixations) was monitored using the *Mobile Eye model 1.35 ASL*®. To analyze gaze, the course was divided into four areas: initial area, middle area, final area and an exit area. Young and elderly people, when walking in initial area, spent more time looking at final and middle areas than to the initial area, the exit area or the outside ($F(1,24)=23.26$, $p<.01$). When they were walking in middle area or in final area both groups looked more to final area and to exit area than to other places ($F(1,24)=7.06$, $p<.05$) and ($F(1,24)=95.91$, $p<.01$), respectively. The elderly during those two phases spent more time fixating final area ($t=-2.27$, $p<.05$) and the exit area ($t=-3.9$, $p<.01$). Both groups presented the same visual strategies spending more time looking at final area, followed by middle and initial areas, although the elderly fixate more the near course environment than the young.

Keywords Local of fixation, Duration of fixation, ageing, obstacle course

Introduction

Vision is the sense that provides precise information about one's surroundings, essential to guide people safely around their environment (Hollands, Patla, & Vickers, 2002). During walking with prescribed stepping targets in the walking path, young adults looked an average of two steps ahead (Patla & Vickers, 2003). A variability in the extent to which individuals look ahead, was observed and may range from the next step (Hollands & Marple-Horvat, 2001) to several steps in advance (Chapman & Hollands, 2007), according to task requirements. The elderly subjects fixated the targets to be stepped or the place where the leading foot should land, earlier and longer than the young (Chapman & Hollands, 2006; Di Fabio, Greany, & Zamperi, 2003). However the study of gaze behavior during tasks that specifies the end goal on a cluttered environment was only done with young adults (Patla, Tomescu, Greig & Novak, 2007).

In the present investigation we examined gaze fixation patterns for young and elderly adults during a goal-directed task, with the aim of examining: 1) the extent that the participants look

ahead; 2) differences in fixation patterns between these groups. Our hypothesis was that both groups looked two steps ahead, but the elderly fixated these places longer.

Methods

Participants

Twenty six healthy adults, with a visual acuity >5/10. Participants were divided into two groups: Young (n=14) M_{age}=20.6 (±1.6) years; Elderly (n=12) M_{age}=71 (±3.2) years.

Protocol

Participants were asked to move through an obstacle course with 4.91m length and reach a pre-defined exit location. They were guided with their eyes closed to the starting point. When they heard the starting signal they open their eyes and start to walk. Twelve cones were used as obstacles to be avoided during the course. Their gaze (point and duration of fixations) was monitored using the *Mobile Eye model 1.35 ASL®.*

Statistics

To analyze the gaze, the course was divided into four areas: initial, middle, final (having each one 1.52 m length-about 2 steps) and exit (35 cm). The point and duration of fixations were analyzed in function of the position of the participant in the course: initial, middle or final areas. The point of fixations was directed for five places: initial area, middle area, final area, exit area, or outside the course. The duration of fixations on each place was calculated as a percentage of the total time that participants spent in each position. A mixed model analysis of variance (ANOVA) was submitted to the duration of fixations, considering the five points of fixations and the age groups, for each participant's position (initial, middle and final areas).

Results

Young and elderly people, when were in initial area, spent more time looking at final area (between 4 to 6 steps ahead) and at middle area (between 2 to 4 steps ahead) than to the initial area, the exit area or the outside ($F(1,24)=23.26$, $p<.01$). Although there is no significant difference between age groups, it should be mentioned that the elderly have shown a longer duration of fixation than the young.

Table 1. Percentage of the fixations' duration in function of the participant's position for young and elderly in each point of fixation.

		Participant's Position					
		Initial area		**Middle area**		**Final area**	
		Young ($\bar{x}$ ± SD)	Elderly ($\bar{x}$ ± SD)	Young ($\bar{x}$ ± SD)	Elderly ($\bar{x}$ ± SD)	Young ($\bar{x}$ ± SD)	Elderly ($\bar{x}$ ± SD)
Point of Fixations	Initial area	.80 ± 3.02	.53 ± 1.38	-	-	-	-
	Middle area	7.60 ± 6.95	12.30 ± 8.79	2.59 ± 4.1	2.27 ± 5.32	-	-
	Final area	6.52 ± 6.10	8.53 ± 7.08	10.05 ±10.77	18.49 ± 7.63	4.38 ± 6.25	8.18 ± 5.93
	Exit	1.14 ± 2.19	.77 ± 2.66	7.8 ± 8.26	3.75 ± 4.32	12.33 ±11.71	28.38 ± 8.78
	Outside	.22 ± .56	0 ± 0	3.41 ± 5.81	.98 ± 3.4	4.98 ± 7.83	4.68 ± 5.68
	Total	16.30 ± 8.68	22.13 ± 8.45	23.86 ± 10.6	25.49 ± 5.14	21.69 ±14.56	41.24 ± 8.88

When they were in middle area both groups looked more to final area (between 2 to 4 steps ahead) and to exit area (between 4 to 6 steps ahead) than to the other places ($F(1, 24)=7.06$, $p<.05$). The elderly spent more time fixating final area during that phase than the young ($t=-2.27$, $p<.05$). When they were in final area both groups looked more to exit area (2 steps ahead) than to other places ($F(1,24)=95.91$, $p< .01$). However the elderly spent more time fixating the exit area than the young ($t=-3.9$, $p<.01$).

Conclusion and discussion

Regardless of participant's position, both groups seem to sample the same visual cues.When choices are required regarding trajectories to achieve a pre-defined goal and avoiding obstacles, it appears that young and elderly adults chose to make longer fixations to places located between 2 to 6 steps ahead than to the other places. However the elderly made longer fixations to the places located between 2 to 4 steps ahead than the young. The elderly fixate more time the near course environment than the young.

The extension with which both groups fixated the path ahead approaches Chapman and Hollands (2007) results and not the ones obtained by Hollands and Marple-Horvat (2001) and Patla and Vickers (2003). It seems that in a dual task the need of scanning the environment influences the distance that participants fixate ahead.

Acknowledgements

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Gross Mechanical Efficiency of the combined arm-leg (Cruiser) ergometer: a comparison to cycling and handcycling

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Abstract The combined arm-leg (Cruiser) ergometer is assumed to be a relevant testing and training instrument in the rehabilitation of patients with a lower limb amputation. Yet its efficiency and submaximal strain have not been established. Ten healthy able-bodied men and twelve healthy able-bodied women enrolled in four discontinuous submaximal graded incremental exercise tests. The same protocol was used of seven bouts of three minutes between 20 and 45 W (5 W increments) on the Cruiser ergometer, bicycle ergometer, handbike and again Cruiser ergometer. Oxygen uptake (O_2), carbon dioxide output (CO_2), ventilation (VE), breathing frequency (BF), respiratory exchange rate (RER), heart rate (HR) and rate of perceived exertion (RPE) were measured. Gross Mechanical Efficiency (GE) was determined from power output and submaximal steady state energy cost. Repeated measures anova was performed to evaluate main effects of exercise mode, exercise intensity and gender, and their interactions ($p<0.05$). Cruiser GE did not differ from cycling (45W; male:13.2±1.9%, female:14.6±1.9%), but was higher than in handcycling (45W: male:11.2±0.8%, female:12.2±2.1%; $p<0.05$). A comparable cardiorespiratory strain was established between Cruiser and bicycle test, but a significantly higher cardiorespiratory strain was found for handcycling. The repeated Cruiser test showed no differences compared to the initial Cruiser test. Under the current testing conditions, male appeared less efficient than female. It can be concluded that GE and cardiorespiratory strain in submaximal Cruiser exercise is comparable to leg cycling under the current submaximal testing conditions. This suggests that the Cruiser ergometer can be a suitable instrument to use in training and exercise testing in patients with a lower limb amputation.

Keywords Ergometry, Gross Mechanical Efficiency (GE), submaximal exercise, physical strain, rehabilitation, lower limb amputation, exercise testing

Introduction

From earlier research it is known that in the rehabilitation after lower limb amputation training in prosthetic walking should be accompanied by some forms of endurance exercise training with the aim of improving fitness. (Chin et al. 2002) Before commencing exercise training, an appropriate maximal exercise test is necessary to determine individual work capacity and based on that advice individual training intensity. (Fletcher et al. 1988) The Cruiser ergometer (Enraf-Nonius,

Delft, The Netherlands, figure 1) combines cyclic arm and leg exercise in the sitting posture. In the early stage of recovery after lower limb amputation, the Cruiser ergometer may prove a practical training and testing device, while the patient sits supine and the healthy leg and upper body can comfortably exercise. In the current study, the main goal was to determine the Gross Mechanical Efficiency (GE), submaximal cardiorespiratory strain and subjective strain in healthy able-bodied men and women during standardized submaximal Cruiser exercise in comparison to two other exercise modes: bicycle ergometry and handbiking. In addition the repeatability of Cruiser exercise was evaluated in the same experiment.



Figure 1. The Cruiser (combined arm-leg) ergometer

Methods

Twenty-two healthy participants (10 men and 12 women) enrolled in the present study. All the participants performed four discontinuous submaximal graded incremental exercise tests on the Cruiser ergometer, bicycle ergometer, handbike and again Cruiser ergometer. Each exercise test consisted of seven bouts of three minutes submaximal exercise at 20W, 25W, 30W, 35W, 40W, 45W and again 20W. The different cardiorespiratory measures: oxygen input (VO_2, (ml/ min)), carbon dioxide output (VCO_2 (ml/min)), breathing frequency (BF (breaths/min)), maximal ventilation (VE (L/min)) respiratory exchange rate (RER) and heart rate (HR in beats/minute) on the Cruiser, bicycle ergometer and handbike were measured during the last thirty seconds of each of seven submaximal bouts. Between each two bouts, the subject had a thirty seconds rest period in which the rate of perceived exertion (RPE) was determined on a ten points scale. (Borg et al. 1982) In each new exercise bout the external work load was gradually increased from zero to the desired work load, within approximately five seconds. GE was determined from power output and submaximal steady state energy cost. Repeated measures anova was performed to evaluate main effects of exercise mode, exercise intensity and gender, and their interactions ($p<0.05$).

Results

Cruiser GE did not differ from cycling (45W; male:13.2±1.9%, female:14.6±1.9%), but was higher than in handcycling (45W: male:11.2±0.8%, female:12.2±2.1%; $p<0.05$). A comparable cardiorespiratory strain was established between Cruiser and bicycle test, but a significantly higher cardiorespiratory strain was found for handcycling. The repeated Cruiser test showed no

differences compared to the initial Cruiser test. Under the current testing conditions, male appeared less efficient than female.

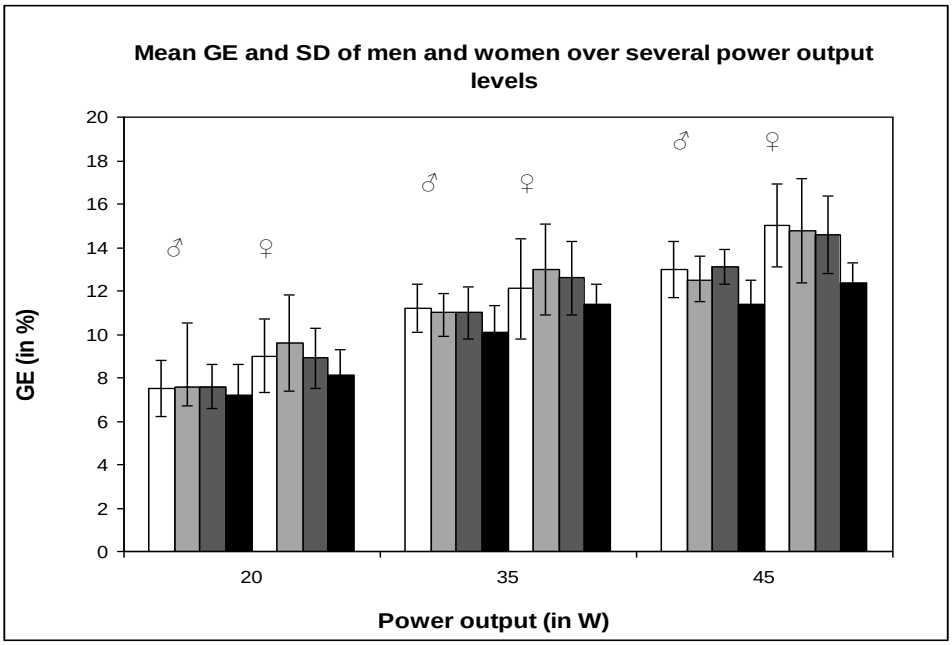

Figure 2: Representation of Gross mechanical efficiency (GE) (mean ± SD) for men (♂) and women (♀) over the several different output levels (20, 35 and 45 W) and three different modes Cruiser pre (white) and post test (light grey), bicycle test (dark grey) and handbike test (black). All values were determined during the last 30 seconds of every exercise phase.

Conclusion and discussion

GE and physical strain in submaximal exercise on the Cruiser ergometer are comparable to cycling exercise. The perceived exertion on the Cruiser ergometer is less than on the handbike. The main advantage for patients with a lower limb amputation of the Cruiser ergometer is the safe and comfortable exercise of a large muscle mass. Exercising on the bicycle ergometer without prosthesis is for patients with a lower limb amputation only possible with one leg and exercising on the Cruiser ergometer is possible with one healthy leg, two healthy arms and trunk. This makes the Cruiser ergometer probably a suitable instrument to use in exercise testing and training in patients with a lower limb amputation.

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Physical activity in adults with cerebral palsy

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Abstract Physical activity is an important aspect of a healthy lifestyle. This study aims to objectively quantify the level of daily physical activity in adults with cerebral palsy (CP), and to study associations with personal and CP-related factors. Seventy-two adults with spastic CP (25-45 years) without severe cognitive impairment participated. In two cross-sectional studies (unilateral and bilateral CP) daily physical activity level was measured with an accelerometry-based Activity Monitor and compared with able-bodied age-mates. Main outcomes were duration of dynamic activity (minutes/day) and intensity of activity (motility, gravitational acceleration [g]). Personal and CP-related factors (age, gender, level of education, muscle tone, limb distribution and gross motor functioning [GMFCS]) were assessed. In adults with bilateral CP mean duration of dynamic activities (116±53 versus 157±50 min/day, $p \leq 0.01$) and mean motility (0.020±0.007g versus 0.027± 0.007g, $p \leq 0.01$) were significantly lower compared with able-bodied age-mates. In contrast, adults with unilateral CP had similar durations of dynamic activities as able-bodied age-mates (152±50 versus 161± 58 min/day; $p=0.66$). Other aspects of daily physical activity were also similar between those with unilateral CP and able-bodied controls. Adults with bilateral CP and a higher level of gross motor functioning had higher duration ($p \leq 0.01$) and intensity ($p \leq 0.01$) of dynamic activity than those with a lower level of gross motor functioning. Other personal and CP-related characteristics were not associated with level of daily physical activity in both study samples. Adults with spastic bilateral CP, and particularly those with a lower level of gross motor functioning, are at risk for an inactive lifestyle. Adults with unilateral spastic CP had levels of daily physical activity comparable to able-bodied persons.

Keywords Cerebral Palsy, Physical Activity, Accelerometry-based Activity Monitoring Introduction

Introduction

Adults with cerebral palsy (CP) return to rehabilitation care for treatment of worsening symptoms such as pain and fatigue (Jahnsen, Villien et al. 2004). This deterioration over time may lead to difficulties in performing daily activities and, consequently, to an inactive lifestyle. A negative cycle may develop: inactivity leads to lower physical fitness and worsening of symptoms, which in turn lead to further inactivity (Durstine, Painter et al. 2000). Also, comparable to persons with other disabilities, inactivity may negatively influence health-related quality of life and may increase the risk of cardiovascular disease and diabetes. Despite the expectation that persons with disabilities are at a high risk for an inactive lifestyle, only limited information is available regarding the level of daily physical activity in adults with CP. This study aims to objectively quantify the

level of daily physical activity in adults with spastic CP, and to study associations with personal and CP-related factors.

Methods

Seventy-two adults with spastic CP (25-45 years) without severe cognitive impairment participated. In two cross-sectional studies (unilateral (*n*=16) and bilateral (*n*=56) CP) daily physical activity level was measured with an accelerometry-based Activity Monitor and compared with able-bodied age-mates. Main outcomes were duration of dynamic activity (minutes/day) and intensity of activity (motility, gravitational acceleration [g]) (Nieuwenhuijsen, van der Slot et al. 2009). Personal and CP-related factors (age, gender, level of education, muscle tone, limb distribution and gross motor functioning) were assessed. Gross motor functioning was classified according to the GMFCS, which is a five-level classification system grading severity of gross motor limitations. The level of satisfaction with level of daily physical activity was measured on a visual analogue scale of 0-10 cm (van der Slot WM, Roebroeck et al. 2007).

Results

In adults with bilateral CP (*n*=56) duration of mean dynamic activities (116 ± 53 versus 157 ± 50 min/day, $p \leq 0.01$) and mean motility (0.020 ± 0.007g versus 0.027 ± 0.007g, $p \leq 0.01$) were significantly lower compared with able-bodied age-mates (Figure 1). In contrast, adults with unilateral CP (*n*=16) had similar durations of dynamic activities as able-bodied age-mates (152 ± 50 versus 161 ± 58 min/day; $p = 0.66$). Other aspects of daily physical activity were also similar between those with unilateral CP and able-bodied controls. Adults with bilateral CP and a higher level of gross motor functioning had higher duration ($p \leq 0.01$) and intensity ($p \leq 0.01$) of dynamic activity than those with a lower level of gross motor functioning. Other personal and CP-related characteristics were not associated with level of daily physical activity in both groups.

The mean level of satisfaction with level of daily physical activity was moderate and comparable in adults with bilateral CP (6.7 ± 2.3 cm) and unilateral CP (n =15; 7.2 ± 2.6 cm) ($p = 0.12$). In persons with unilateral CP a negative correlation was found between satisfaction with the level of daily physical activity and mean duration of dynamic activities a day ($Rs = -0.66$, $p = 0.007$), in bilateral CP no relationships ($Rs = -0.13$ to 0.09, $p's > 0.05$) were demonstrated with the 3 main aspects of level of daily physical activity.

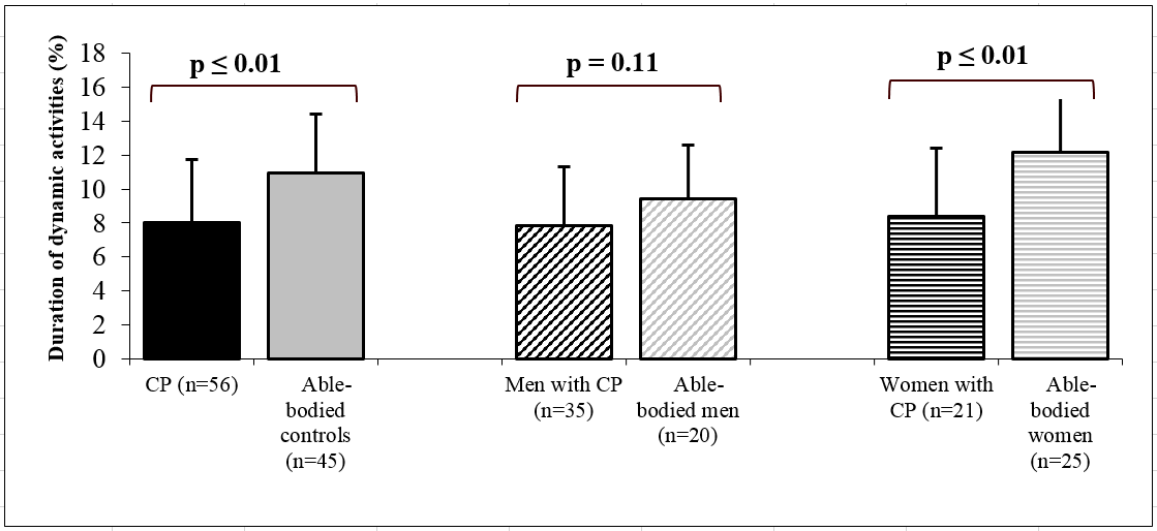

Figure 1a. Mean duration of dynamic activities in adults with spastic bilateral cerebral palsy and able-bodied age-mates, as percentage of a 24-h period.

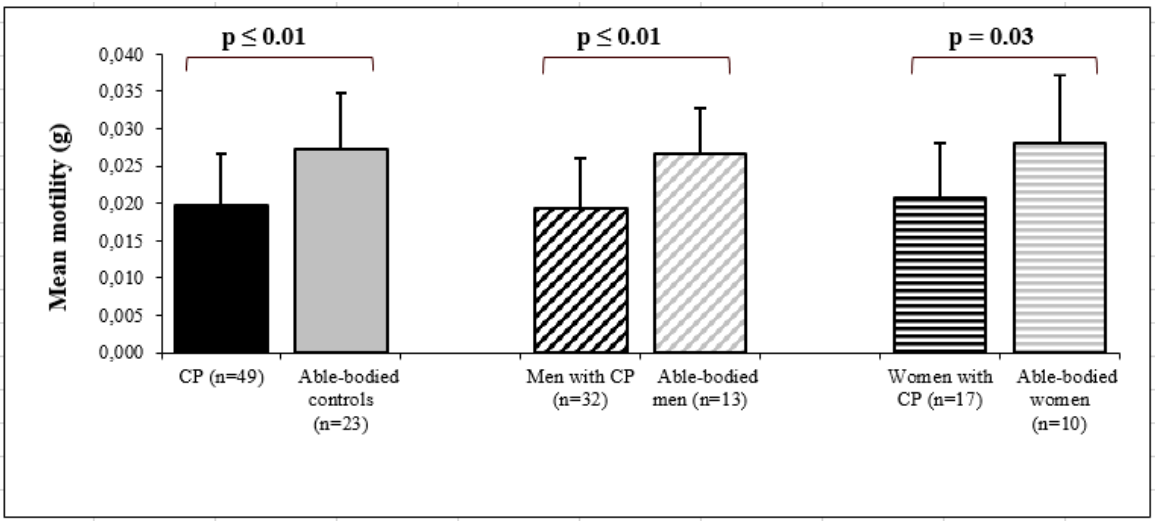

Figure 1b. Intensity of activities (mean motility) in adults with spastic bilateral cerebral palsy and in able-bodied age-mates, expressed in gravitational acceleration (1 g = 9.81 m/s2).

Conclusion and discussion

Adults with spastic bilateral CP, and particularly those with a lower level of gross motor functioning, are at risk for an inactive lifestyle. Adults with spastic unilateral CP had levels of daily physical activity comparable to able-bodied age-mates. It should be noted that all adults with unilateral CP were ambulatory and the sample size was small, which limits the generalisability of these results.

Gross motor functioning was significantly associated with the main aspects of level of daily physical activity in spastic bilateral CP. No other associations with personal and CP-related characteristics were found in both groups.

In contrast to adults with bilateral CP, persons with unilateral CP with longer durations of dynamic activities appeared to be less satisfied with their level of daily physical activity. A possible explanation may be that adults with unilateral CP who function at a higher daily physical activity level, intend to have 'normal lives' and set higher goals or perform more demanding tasks.

Further analysis of sedentary time and high- intensity activities is of interest. Studies into the relationships between level of daily physical activity, health-related fitness, and fatigue and pain symptoms may further elucidate the significance of physical activity to optimize health in adults with CP.

Acknowledgements

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Feasibility and effects of overnight ES-induced muscle activation using ES-horts in spinal cord injury

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Abstract *Objective:* To study the 1. feasibility of electrical stimulation (ES)- shorts during overnight use, 2. the effects of prolonged surface ES-induced muscle activation on muscle fatigue and 3. muscle oxygenation in persons with spinal cord injury (SCI). *Methods:* Design: Pre- post-test intervention design. Setting: Rehabilitation Research center. Participants: Eight participants with SCI (ASIA A or B) Intervention: ES-induced activation of the gluteal, hamstrings and quadriceps muscles in a 2 weeks overnight stimulation protocol, 8 hours per night. Custom-made ES-shorts were developed for this study. Main Outcome Measures: A questionnaire was used to determine feasibility of the ES-shorts., Muscle fatigue and oxygenation after arterial and venous occlusion were determined. *Results:* Feasibility of the ES-shorts in general was good, and ES did not disturb sleep. After 8 hours of activation muscles still contracted, although mean contraction size was significantly lower at the end of the night compared to the start. After 2 weeks of ES-induced muscle activation, gluteal oxygenation while sitting, was not significantly higher compared to the pre-test ($p=0.77$). No significant differences were found between pre- and post-test in mean oxygen uptake ($p=0.31$) after arterial occlusion, or blood flow after venous occlusion. *Conclusions:* Overnight ES-induced muscle activation in SCI is a feasible method that does not interfere with sleep. Muscles still contracted after 8-hours of ES-induced activation, although contraction size significantly decreased during the night. No significant effects were found on muscle fatigue, oxygenation or blood flow after 2 weeks of muscles activation, compared to the pre-test.

Effect of rocker shoes on plantar pressure pattern in healthy female runners

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Abstract *Purpose:* The efficacy of rocker shoes in reducing the forefoot pressure has been shown in walking. The aim of this study was to examine the effect of a rocker shoe design on forefoot pressure during running. *Methods*: Eighteen healthy female runners participated in this study. In-shoe plantar pressures were recorded during running with the standard running shoes and rocker shoes. Peak pressure (PP), maximum mean pressure (MMP) and force-time integral (FTI) were determined for seven foot areas. Shoe comfort was assessed after each shoe condition. The effects of shoes on the different outcome variables were statistically analyzed using a linear mixed model. *Results:* Running with the rocker shoes caused a significant reduction ($p<0.001$) in PP, MMP and FTI in the central (24%, 17% and 17% respectively) and lateral forefoot (27%, 23% and 28% respectively). FTI and MMP were also reduced significantly by 11% and 12% in the medial forefoot while running with rocker shoes. Running with rocker shoes also resulted in a significant increase in all pressure parameters at the heel region ($p<0.001$). Running with rocker shoes received a significant ($p<0.01$) lower comfort rate than running with standard shoes. *Conclusion:* Rocker shoes have the potential to be one of the treatment options for runners who are recovering from metatarsalgia or a stress fracture of the forefoot region, as it reduces plantar pressure in the forefoot region. The increased loading at the heel region and low levels of comfort are drawbacks of the rocker shoes.

Muscular rehabilitation and training using a low-inertia device

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Abstract *Purpose:* The aim of this work is to project a new device for muscular rehabilitation and training applied to sporting performance, aesthetic or physiotherapeutic purposes. The simple device was projected and to adapted to the conventional fitness equipment. *Methods:* Some restrictions were imposed for the mechanism project such as: reduced number of components; total movable mass reduced; simple operation; possibility of simplified. Based on these restrictions and the desirable biomechanical adjustment and control characteristics, the mechanism was idealized, using a Cam, a follower and a spring. Mathematical model of the system was developed and the mechanism was evaluated using a simulation model generated by Adam´s Program. A biceps joint system was chosen for testing validation. A torquemeter machine was project and manufactured for measure the biceps torque. The cam-follower-spring system was manufactured and validated using a judo athlete. *Results:* The virtual project of mechanism tested showed an available torque similar to the torque defined by mathematical model. The prototype built attached to the torquemeter chassis showed that the cam-follower-spring can provide an output torque similar to the measure torque with approximately 10% relative error. *Conclusions:* A new strength device for muscle training was designed to prevent the inertia effect substituting masses by the cam-follower-spring system and modifying the cam profile to increase or to diminish the torque resistance generated by the spring according the direction of inertia forces in a specific physical exercise. In such a way, the resistant torque is kept proportional to the muscle capacity during all the movement, since that the acceleration and movement speeds are maintained in accordance to the predetermined pattern of movement. For this system, this pattern can involve high speeds and acceleration training movements.

Paralympic ice-skating; what are the steps for a classification system? A review

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Abstract A limited number of sports are included in the Winter Paralympics. Adding ice-skating (i.e. figure skating, long-track and short-track speed skating) could broaden the Paralympic Winter scope. The purpose of this review was to make a first step towards development of an evidence-based classification system for ice-skating, as is required by International Paralympic Committee (IPC) to include a new sport at the Paralympics. Pubmed was searched from 1985 to 2013 on Paralympic classification and performance determining factors in ice-skating. Seventeen articles about classification and 34 articles about ice-skating were included. Information provided by the IPC and International Skating Union was added. No studies were found about impaired ice-skating. IPC stated three groups of eligible impairments: biomechanical, visual and intellectual. The impact of impairments on activity limitation is the main determinant in classification. Therefore, understanding performance determining factors in ice-skating is important. Literature on speed skating defines aerodynamic body position, lateral movement of the thigh, leg and foot, stride length, push-off, hanging phase, balance and pacing as performance determining factors. Those factors show similarities to performance determining factors of Paralympic running. In figure skating jumps, including forward propulsion, jump height, landing technique, holding the counterpart and balance were defined. For further development of classification it is advised to start with the non-jury sports: long-track and short-track speed skating. A similar evidence-based biomechanical test battery as exists in Paralympic running, which is also a standing sport with similar performance determining factors, could be developed. Balance tests should be added, that are of particular importance in skating. Lastly, pacing behavior seems important for classifying intellectual impairment.

Keywords Impairment, ice-skating, Paralympic, classification

Introduction

The Winter Paralympics of Sochi 2014 included five sports: biathlon, cross-country skiing, ice sledge hockey, wheelchair curling and alpine skiing, of which the last was subdivided into skiing and para-snowboarding. Five sports (692 competing athletes) is only small number compared to the 23 sports (4237 competing athletes) of the Summer Paralympics of London 2012 (www.paralympic.org). To have more athletes competing at the Winter Paralympics, more sports could be included. A suitable candidate to broaden the variety of the Winter Paralympics is ice-skating, a popular sport at the Winter Olympics that includes figure skating, long-track and short-track speed skating. To be included in the Paralympic program, an evidence-based and sport specific classification system must be developed, that groups eligible athletes into classes based on impact of impairment on sports performance and minimizes the impact of impairment competition outcome (Tweedy & Vanlandewijck, 2011). The existing classification handbook for

ice-skating (existing since march 2012) is based upon the American Medical Association Guides to the Evaluation of Permanent Impairment (Rondinelli Guides) and was the starting point to denote the importance and the complexity of classification of ice-skating sports (www.impairedskating.org). However, this handbook did not approach classification from an evidence-based perspective. The present review aims to further develop classification of impaired ice-skating by further providing a scientific evidence-base. Performance determining factors will be identified, to be able to understand the activity limitations associated with impairment for ice-skating.

Methods

Pubmed was searched from 1985 to 2013 on Paralympic classification and performance determining factors in ice-skating. Mesh terms are presented in Table 1. Documents and information of the IPC site, International Skating Union site, International Olympic Committee site, American Association on Intellectual and Developmental Disorder site and the impaired skating classification site were added.

Table 1. Mesh-terms used for the Pubmed search.

	Subjects				
	Classification	Figure skating	Long-track speed skating	Short-track speed skating	Performance determinants
Mesh-terms	Classification	Figure skating	Speed skating	Short track speed skating	Muscle
	Paralympic	Figureskating	Speedskating	Short track speedskating	performance
			Speed skaters	Short-track speed skating	
			Speedskaters	Short-track speedskating	
				Shorttrack speed skating	
				Shorttrack speedskating	

Results

The literature search resulted in 19 articles relevant to classification and 34 relevant to ice-skating, of which 13 for long-track and 3 for short-track speed skating, 11 about figure skating and 7 others. Also5 websites and 3 documents of the IPC site were included.

The IPC classifies three overall impairment types: biomechanical, intellectual and visual impairment. The first two are classified by a functional classification system as recommended by the IPC: classification is based on limitation of performance determining factors due to impairment. Visual impairments are still classified by the traditional medically based system, that is based on health conditions. The nowadays preferred functional classification system aims to reduce the effect of eligible impairment type on competition. Therefore, to develop an evidence-based functional classification system, performance determining factors of ice skating must be found and understand to know how these are influenced by the impairment (Tweedy & Vanlandewijck, 2011).

Several performance determining factors of long-track and short-track speed skating and figure skating are extracted from literature. Literature on speed skating defines aerodynamic body position, push-off (Houdijk et al., 2000), lateral movement of the thigh, leg and foot, stride length (Chang et al., 2009), hanging phase (Hesford et al., 2013), balance (Park et al., 2012) and pacing (Smits et al., 2013; Roelands et al., 2013) as performance determining factors. Those factors show similarities to performance determining factors of Paralympic running (Beckman & Tweedy, 2009). In the jury sport figure skating, jumps including forward propulsion (Bower et al., 2010), jump height, landing technique (Lockwood et al., 2006), holding the counterpart (King et al., 2008) and balance (Tanguy et al., 2008) were defined.

Conclusion and discussion

This review aimed to make a first step in providing a scientific evidence-base to further develop classification in ice-skating. Different performance determining factors of the three able-bodied ice-skating sports could be extracted from literature. For further development of classification it is advised to start with the non-jury sports: long-track and short-track speed skating, because involvement of a jury creates more difficulties for objective measurement of impact of impairment. A similar evidence-based biomechanical test battery as exists in Paralympic running, which is also a standing sport with similar performance determining factors as in speed skating, could be developed. Balance tests should be added, that are of particular importance in skating. Lastly, pacing behavior seems important for classifying intellectual impairment.

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Use and satisfaction with adaptive devices in youngsters with upper limb reduction deficiencies

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Abstract The aim of the study is to evaluate the use and satisfaction with adaptive devices (ADs) compared to use and satisfaction with prostheses in youngsters with upper limb reduction deficiency (ULRD). A cross-sectional study using questionnaires was performed. Children with ULRD between 2-20 years old responded to questions about personal and ULRD characteristics, restrictions in activities, preferred solutions for activities, usage, satisfaction and social adjustment with ADs versus prostheses. Of the 221 completed questionnaires, 218 were suitable for the study. More than half (58%) of the participants were boys, 87% had a transversal reduction deficiency (60 % below-elbow). The majority of participants (76%) ever used ADs and 37% ever used prostheses. More than 50% of youngsters had restrictions in activities like using cutlery or tying shoelaces, recreation and leisure, and in household activities. The most preferred solution to overcome restrictions in activities was using the hands and body-parts (>60%, except for using cutlery–39%), followed by receiving help (≤46%), the ADs used for specific activities (≤46%) and last by the prostheses (≤9%). Of the 360 ADs described, 43% were used for self-care –using cutlery, 28% for mobility–riding a bicycle, 13% for recreation and leisure– leisure activities, doing sports and playing a musical instrument. Prostheses were used for mobility, communication, recreation and leisure, and work or employment. Satisfaction with AD was significantly higher than satisfaction and with prostheses ($p<0.01$). Social adjustment was better with ADs than with prostheses. Between the devices provided to youngsters with ULRD, ADs were mostly used and youngsters were more satisfied and better socially-adjusted with ADs than with prostheses. Our results demonstrate that ADs are used successfully as an alternative to prosthetic treatment. The ADs should be included in the standard rehabilitation treatment of youngsters with ULRD.

Keywords Physical and rehabilitation medicine, self-help devices; assistive devices, assistive technology, orthotic devices, congenital upper extremity deformities

Introduction

Youngsters with upper limb reduction deficiency (ULRD) may encounter limitations in activities of daily living (ADLs) such as using cutlery, lifting heavy objects, doing sports, cycling or driving. Although prostheses can be prescribed to overcome activity limitations, many are rejected due to discomfort or lack of functionality (Biddiss, Chau 2007; Postema, van der Donk en al. 1999). Youngsters with ULRD may use alternative solutions, such as adaptive devices (ADs). ADs are

utensils used to facilitate ADLs, and are mostly developed by rehabilitation professionals. Devices that can be mounted on a prosthesis are not considered ADs. Information about the use, satisfaction and social adjustment with ADs in comparison to prostheses is lacking. The aim of the study was to evaluate the use, satisfaction and social adjustment with ADs compared to prostheses in youngsters with ULRD.

Methods

Participants

Participants were recruited throughout eight national rehabilitation centers. Youngsters with ULRD between 2-20 years old and their parents were included in the study.

Protocol

A questionnaire was developed to evaluate personal and ULRD characteristics, difficulties in activities, preferred solutions for activities, usage, satisfaction and social adjustment with ADs. To evaluate satisfaction, the Dutch version of Quebec User Evaluation of Satisfaction with assistive technology questionnaire (D-Quest) was used. Social adjustment was assessed with a subscale of the Trinity Amputation and Prosthesis Experience Scales questionnaire (TAPES).

Statistics

The activities of daily living were grouped according to the domains of International Classification of Functioning, Disability and Health: self-care, mobility, communication, recreation and leisure, domestic life and work/ employment. Paired t-tests were used to compare satisfaction (D-Quest) and social adjustment (TAPES) with ADs with satisfaction and social adjustment with prostheses.

Results

A total of 360 ADs were used by 76% of 218 participants (n=166). Eighty youngsters used or had used prostheses (37%). Participants were mainly boys (58%) and had transversal ULRD (87%).

The majority of youngsters reported having difficulties with activities of daily living such as using cutlery or tying shoelaces, recreation and leisure, and in household activities. To facilitate some of the difficult activities, youngsters used ADs for self-care (using cutlery, 43%), mobility (riding a bicycle, 28%) or leisure activities (sports or playing a musical instrument, 13%, Figure 1). Prostheses were used for self-care (4%), mobility (9%), communication (3%), recreation/leisure (6%), and work (4%). The most preferred solution to facilitate difficult activities was using un- and affected hands and other body-parts (more than 60%), receiving help (more than 50%), using ADs (up to 48%) and prostheses (less than 9%).

The D-quest (Devices) revealed higher satisfaction with the ADs than with the prostheses ($P<0.01$). No difference was found in satisfaction with the rehabilitation services provided for ADs compared to prostheses ($P=0.839$).The social-adjustment (TAPES) with ADs was higher than the social-adjustment with prostheses ($P=0.044$).

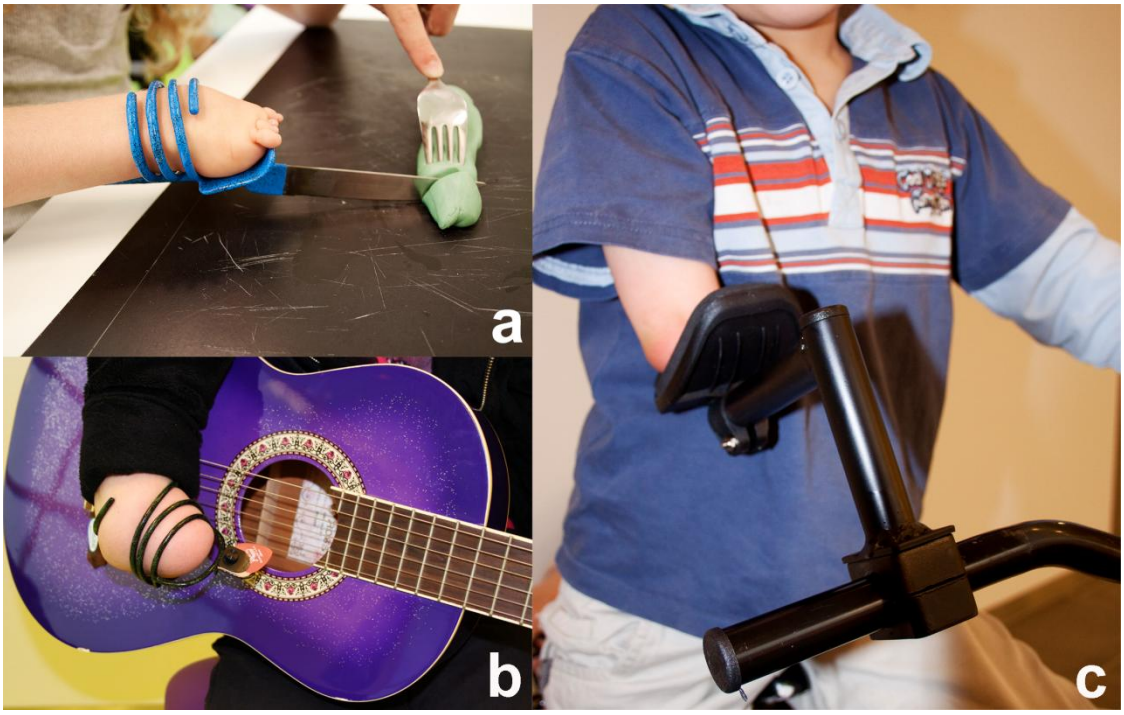

Figure 1. Example of adaptive devices used for eating (a), playing a musical instrument (b) and riding a bike (c).

Conclusion

Youngsters with ULRD used ADs much more than prostheses and they were more satisfied and socially better-adjusted with the ADs. The ADs were mainly used for eating, cycling, sports or playing musical instruments. The ADs should be included in the standard rehabilitation treatment of youngsters with ULRD.

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The effect of 8-week low-intensity wheelchair practice on the glenohumeral contact-forces of novice able-bodied participants

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Abstract Propelling a manual handrim wheelchair is a new task for persons with a lower limb disability, which must be learned at the start of rehabilitation. Handrim wheelchair propulsion is a cyclic bimanual task with a relatively low mechanical efficiency and is associated with overuse injury in long-term wheelchair users. Low-intensity practice has been shown to improve the propulsion technique, peak power production and mechanical efficiency, however little is known about the effects of practice on the glenohumeral contact force. Therefore the purpose of this study was to evaluate the effect of 8-week low-intensity wheelchair practice on shoulder load in combination with propulsion technique and mechanical efficiency. 18 Novice able-bodied subjects were pair matched and randomly assigned to an experimental group (n=9) and control group (n=9). The experimental group received 8 week of low-intensity practice (30% HRR) for two 30-minute trials per week on a motor driven treadmill. During the last minutes of three steady-state 4-min trials of the standardized pre- and post-tests, kinematic, kinetic and physiological data were collected. These data were subsequently analyzed to compare the two groups on changes in glenohumeral joint compression (using a musculoskeletal model), mechanical efficiency and propulsion technique. The experimental group showed a decrease in glenohumeral contact forces; the peak joint force during the push reduced from 251.3 to 203.3N vs. 243.2 to 249.3N in the control group and the mean reduced from 99.4 to 72.9N vs. 91.0 to 89.6N in the control group. Furthermore the experimental group increased in mechanical efficiency and improved their propulsion technique from a high-frequency pattern with high negative work to a low-frequency pattern with less negative work. The decrease in shoulder load and increase in mechanical efficiency both indicate a decreased mechanical strain on the upper body because of the low-intensity practice. Possibly an improved propulsion technique helps to prevent overuse injuries of the glenohumeral joint.

Somatosensory stimulation to augment interlimb transfer: implications for rehabilitation

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Abstract *Purpose:* Sensory input modifies motor output. Somatosensory electrical stimulation (SES) can have 'direct' (contralateral) and 'crossed' (ipsilateral) effects on brain activity, corticospinal excitability and motor performance. We plan to examine a new model of cross-education with special emphasis on rehabilitation of patients with unilateral orthopedic injuries. The model proposes SES to increase interlimb transfer after training a visuomotor skill. *Methods:* Participants are randomly assigned to the motor practice (MP) only, MP+SES, or SES-only group. During MP, participants perform 300, 5-s-long movement trials and follow a pre-programmed template, using wrist flexion and extension. Mean error between the template and participants' performance is calculated as a measure of motor performance. Using transcranial magnetic brain stimulation, neuronal excitability is assessed before and after the intervention. *Results:* Pilot data in right-handed young adult controls show that MP improves motor performance 33.4% (±12.5) in the trained right hand and also in the non-trained, left hand 19.9% (±10.2), demonstrating a significant cross-education effect. Additional experiments are underway to test the hypothesis whether SES added to MP increases the direct and crossed effects in controls. *Discussion:* In future experiments, we will test the hypothesis whether SES added to MP increases interlimb transfer. To the best of our knowledge, no study assessed the 'crossed' effects of SES on motor performance yet. We will also examine the effects of timing of SES, to test whether SES applied before (priming), during, or after (consolidation) MP would have the most beneficial effects on motor performance and interlimb transfer. *Conclusion:* If the hypothesis is tenable, SES could be added to unilateral MP during the rehabilitation of patients from an orthopedic injury such as wrist fracture (Zijdewind et al. 2006) and anterior cruciate ligament reconstruction (Papandreou et al. 2013).

Keywords Somatosensory stimulation, Interlimb transfer, motor learning

Introduction

Sensory inputs are necessary for the performance of accurate movements and disruption of sensory inputs results in inaccurate movements (Rothwell et al. 1982). Also, sensory inputs are necessary to learn new motor skills (Rosenkranz and Rothwell 2012). It has been suggested that providing sensory input can restore motor function in patients with deficient sensory functions.
Somatosensory electrical stimulation (SES) can increase corticospinal excitability (Kaelin-Lang et al. 2002) and motor performance (Hunter, Critchlow, Enoka 2004). Recent studies suggest that SES can also increase excitability of the primary motor cortex ipsilateral to the SES (Shin and Sohn 2011). The modulation of excitability of both motor cortices after unilateral SES is in line with the observation that motor practice (MP) of one limb also increases task performance in the contralateral limb, referred to as cross-education or interlimb transfer. Such interlimb transfer can

have implications for patients with unilateral impairment (Zult et al. 2013). Combining data from these studies, we hypothesize that SES along with MP increases interlimb transfer compared to MP alone.

Methods

Nineteen healthy, right handed participants (age 21.4, 8 males) free of neurological and orthopedic conditions were included in this study after giving written informed consent.

Participants were randomly assigned to one of three groups, receiving either only motor practice (MP), MP + SES or SES only. MP consisted of 300 5-s-long visuomotor training trials in which participants were asked to follow a preprogrammed template as accurately as possible using wrist flexion and extension. The SES intervention, targeting the radial and median nerves above the elbow, consisted of 10Hz-trains delivered at 1Hz for 25 minutes at an intensity of twice the perceptual threshold and was delivered only during the training blocks. Corticospinal excitability, short-interval intracortical inhibition (SICI) and visuomotor performance were assessed pre- and post-intervention in the left and the right hand.

Visuomotor performance was quantified in degrees as the mean deviation from the preprogrammed template. MEPs were normalized to the maximal compound action potential (Mmax). SICI was expressed as a percent of test pulse MEP. We tested the hypothesis by a one-way ANOVA on the gain scores that were computed for the three groups, followed by Bonferroni post-hoc test to identify the means that differed at $p < 0.05$.

Results

The three groups had similar visuomotor performance at baseline, which increased 31.4% (±5.6) in MP and 30.9% (3.8%) in the MP+SES in the right, practiced hand. These gains were greater than the 14.4% (±4.1) increase in the SES-only group ($F_{2,18} = 11.91$, $p = 0.001$, interaction on gain scores). There was also a time main effect in the left, non-trained hand and MP, MP+SES and SES improved similarly 15.8%, 18.4% and 10.5% ($F_{1,16} = 47.7$, $p < 0.001$) but no group by time interaction ($F_{2,18} = 1.36$, $p = 0.28$).

After practice with the right hand, corticospinal excitability increased non-significantly in the left M1 21.9 (±71.8%), 24.8 (±46.6%) and 68.3 (±16.8%) in the three groups ($F_{2,17} = 0.16$, $p = 0.85$, interaction on gain scores). In the right (non-trained and non-stimulated) M1, corticospinal excitability increased non-significantly 75.9% in SES (±96.8), but decreased non-significantly in MP (-12.9% ± 18.8) and the MP+SES group (-23.9% ± 26.9; $p > 0.05$; $F_{2,17} = 5.64$, $p = 0.015$, interaction on gain scores). The intervention did not affect SICI in either M1.

Conclusion and discussion

Adding SES to visuomotor practice did not improve visuomotor performance in the trained hand further in healthy young participants compared with visuomotor practice alone. The finding is in contrast with data in stroke patients in whom a SES-only treatment increased motor performance compared with idle-time controls (Wu, Seo, Cohen 2006). One possible explanation for the discrepant data is that the healthy participants in the present study achieved a high level of learning and SES could not further potentiate this learning effect. The participants also had normal sensory function compared with patients who often present with some sensory dysfunction. It is unclear if SES could speed motor recovery of the injured limb. The 14.9%

overall interlimb transfer in the three groups was independent of the type of motor practice. Against the hypothesis, SES did not augment the transfer. Although previous studies used SES alone as an intervention to improve motor performance before motor practice (Hunter, Critchlow, Enoka 2004), the current study showed greater improvements in the groups that did VMP compared to the group that only received SES. The parameters measured using TMS did not show any significant changes. Thus, SES at an intensity of twice the perceptual threshold does not augment motor learning and interlimb transfer in healthy young participants and does not modify cortical and corticospinal excitability. However, it is conceivable that patients with an orthopedic condition (wrist fracture, ACL tear) would respond favorably to such of somewhat higher intensity SES protocol akin to the responses seen in patients with a neurological disorder.

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Effects of Wheelchair Cushions and Pressure Relief Maneuvers on Ischial Interface Pressure and Blood Flow in People With Spinal Cord Injury

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Abstract The overall goal of this study was to investigate the effectiveness of the two important prevention methods for pressure ulcers, namely wheelchair cushions and partial pressure reliefs, and to evaluate the variance in the effectiveness of the partial pressure reliefs between cushions. Seventeen people with a spinal cord injury participated in this study. The ischial interface pressure (IP) was measured with a custom FSA interface pressure sensor and the blood flow was measured with laser Doppler flowmetry. The participants carried out three forward and two sideward leans on the ROHO high profile®, Jay J2^{tm} and Matrx® Vi wheelchair cushions. Cushion type had a main effect on the pressure; the ROHO high profile® and Jay J2^{tm} both induced lower interface pressures than the Matrx® Vi. Pressure relief maneuvers had a significant main effect on the ischial IP; all maneuvers except for the small frontward lean resulted in a significant reduction in IP compared with upright sitting. Regardless of the cushion being used, the pressure relief maneuvers resulted in very large reductions in IPs and significant increases in buttock blood flow. Only the small frontward lean was shown to be ineffective in reducing pressure or increasing blood flow. The results of the study highlight the importance of positioning wheelchair users in a manner that facilitates in-seat movement.

Keywords Pressure ulcer, Rehabilitation, Spinal cord injuries, Wheelchairs

Introduction

Despite extensive research, pressure ulcers are one of the most common secondary complications after spinal cord injury (SCI), affecting >50% of the people during their lifetime (Krause, Broderick et al, 2004; Raghavan, Raze, et al., 2003). Wheelchair cushions and pressure relieving maneuvers are two common forms of prevention. Although these methods are widely used, evidence about the preventive impact is limited. Besides, there are no studies done about the combined effect of the maneuvers and cushions. This combined effect is relevant to investigate because differences in the material construction of the cushions (eg. foam, gel, air) may lead to different responses to the pressure relief maneuvers.

The objective of this study was to explore the effectiveness of both prevention methods with respect to interface pressure(IP) and blood flow at the buttocks. Three research questions were investigated: 1) What is the effect of different PR maneuvers on pressure and blood flow under the ischial tuberosities (ITs)?, 2) What is the effect of the different cushions on pressure and blood flow under the ITs?, 3) Does PR effectiveness differ across cushions?

Methods

Participants

Seventeen individuals with a complete or incomplete spinal cord injury or disorder (SCI/D) participated. Participants had to be ≥ 18 years, be ≥ 2 years post injury, use a wheelchair as their primary mobility device and be able to maintain pressure relief positions for at least 60 seconds. Persons with current pressure ulcers on both ITs were excluded from the study.

Protocol and instrumentation

Three commonly described wheelchair cushions with disparate designs were selected for the study; the air-based ROHO high-profile ®, the gel-based Jay ® J2^{tm}, and the foam-based Matrx® Vi. Five different pressure relief maneuvers were studied (Figure 1) , namely A) small frontward lean, B) intermediate frontward lean, C)full frontward lean , D) intermediate sideward lean, E) Full sideward lean. A custom made pressure sensor and Doppler Laser Flowmetry (LDF) probe were attached to the overlying skin of one of the ITs.

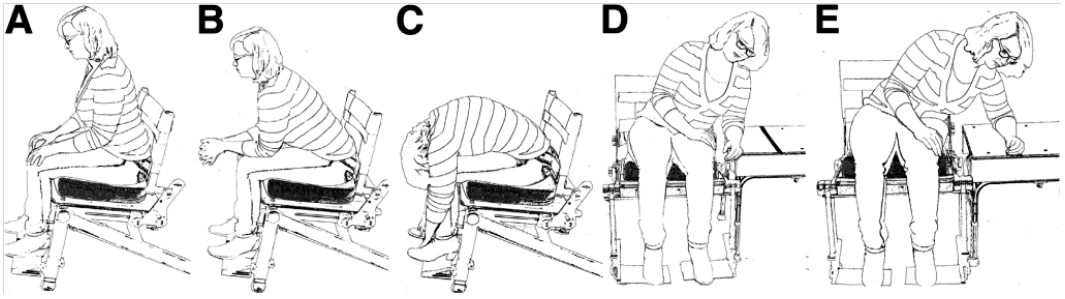

Figure 1. Illustrations of pressure relief maneuvers on the test chair: (A) small frontward lean, (B) intermediate frontward lean, (C) full frontward lean, (D) intermediate sideward lean, and (E) full sideward lean.

Statistics

A linear mixed model test was used for all comparisons. The repeated covariance type was selected using the Schwarz's Bayesian Criterion (BIC). A post-hoc test with no correction was executed to indicate differences between cushions, PRs and PRs on different cushions. To avoid a type I error, a False Discovery Rate correction was applied.

Results

A main effect of cushion type was found on the ischial IP ($p < .001$). Across all postures, ischial IP was significantly higher ($p<.001$) while participants were sitting on the Matrx® Vi (mean = 92.3) than on the Jay J2^{tm} (mean = 73.9) and the ROHO high profile ® (mean = 74.4), with no significant differences between the ROHO and the J2 ($p=.9$).

PRs had also a significant main effect on the pressure ($p<.001$), with all maneuvers resulting in a significantly lower IP than upright sitting, except for the small frontward lean The full frontward

and full sideward leans reduced the ischial IP significantly more than all other maneuvers (p<.001), but were not significantly different from each other (p = .12).

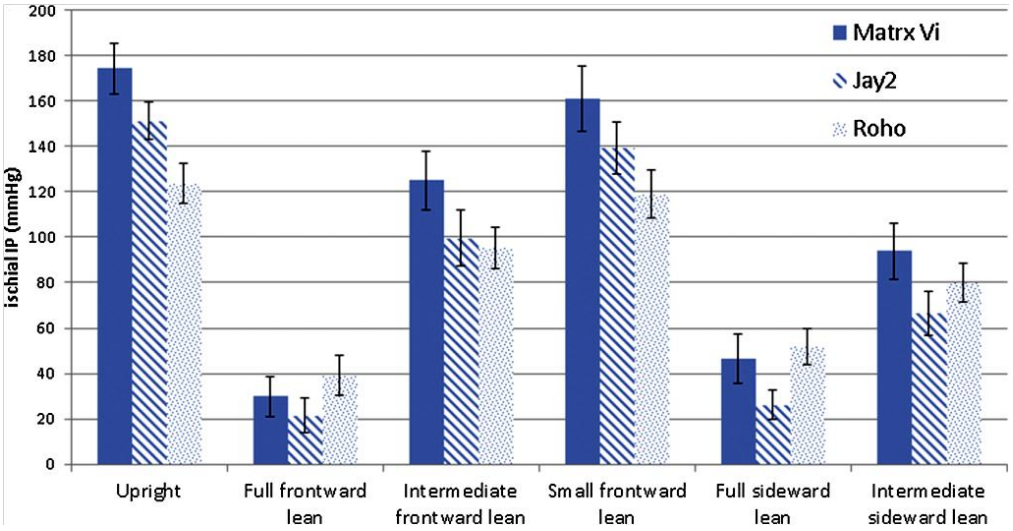

Figure 2 Ischial IP during pressure relief while seated on the Matrx Vi, Jay J2, and ROHO high profile cushions.

A significant interaction effect (p<.001) was found between posture and cushions, which suggests that reduction of ischial IP for a given pressure relief maneuver differed across cushions. The ROHO achieved the lowest ischial IP values in erect sitting (p<.001), but the Jay J2 achieved the greatest ischial IP reduction from upright to full forward (86% reduction) and sideward leans (figure 2).

Even though the blood flow signal varied strongly across subjects, flux significantly varied across postures (P<.001). Blood flow during upright sitting and small forward leans was significantly lower than blood flow during the full and intermediate leans in both forward and sideward directions. No significant effect of cushion type was found on the flux (p=.89), and a significant interaction was not found between the cushions and posture (p=.67).

Conclusion and discussion

The results highlight the importance of positioning wheelchair users in a manner that facilitates in-seat movement. Regardless of the cushion being used, the pressure relief maneuvers studied resulted in very large reductions in IP and significant increases in buttock blood flow. Only the small frontward lean, where a person leans forward with hands on knees, was shown to be ineffective in reducing pressure or increasing blood flow.

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Effects of one-day low-intensity Cruiser ergometer exercise: efficiency of one versus two legs

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Abstract The purpose of this study was to investigate adaptations in gross mechanical efficiency (GE) over a one-day low intensity exercise program on a combined arm-leg (Cruiser) ergometer with one leg versus two legs. Twenty-eight healthy able-bodied male subjects participated in this training study. Subjects were divided into two groups of comparable age. One group was instructed to use both legs and arms, the other group used only one leg and both arms during pre and post tests (each test: 3x4min at 40W at 50 rpm) and the exercise program (7 sessions of 10min: 2x 4min 40W and 50rpm, 2 min rest) on the Cruiser ergometer. GE, oxygen uptake (VO_2), respiratory exchange ratio (RER), heart rate (HR), and rating of perceived exertion (RPE) were measured. For both groups HR and RPE decreased significantly between pre and post test. The one-leg exercise group showed a significant increase in GE (+ 1.7%), the two-leg exercise group did not. However, no significant difference in improvement in any variable was found between both groups. The results indicate that adaptations in GE can be seen after a short submaximal exercise program on a Cruiser ergometer when only one leg is used. This finding may have important implications for the use of the Cruiser ergometer in the rehabilitation of patients with a leg amputation. When both legs are involved, the improvement of GE is not found. However, since no significant difference in GE adaptations was found between both groups, the study needs to be replicated using a larger sample.

Keywords Cruiser ergometer, gross mechanical efficiency, one-leg exercise, low intensity

Introduction

Physical activity is generally considered to be important for a healthy lifestyle. More specifically, it is crucial for people with a lower limb amputation, since they are often experiencing health problems (like cardiovascular diseases) (Fleury et al. 2013). Combined arm-leg ergometry, using a Cruiser ergometer, seems to be suitable to improve the physical capacity of people with a lower limb amputation (Vestering et al. 2005). The aim of this study was to investigate whether adaptations in gross mechanical efficiency (GE) could be found after one day of low intensity exercise on a Cruiser ergometer and whether differences in this adaptation process could be found between combined upper and lower body exercise with two legs versus one leg only.

Methods

Participants

In this study 28 healthy male subjects between 18 and 30 years of age participated after signing an informed consent. This study was approved by the Local Ethical Board of the Center for Human Movement Sciences.

Research protocol

Subjects were divided into two groups. One group was instructed to use both legs and arms, the other group used only one leg and both arms during pre and post tests and the exercise program on a Cruiser ergometer (Figure 1). The Cruiser ergometer is a hybrid arm-leg training and testing device. Both tests and the exercise program took place on one day.

Pre and post test consisted of three bouts of four minutes exercise at 40W at 50 rpm. Between pre and post test seven exercise sessions of ten minutes (two times four minutes, with two minutes rest in between) at 40W and 50 rpm were undertaken, with twenty minutes rest between the sessions.

The following variables were measured during the pre and post test:

- Main outcome variable: gross mechanical efficiency (GE). GE was determined by the oxygen uptake (VO_2: L/min), respiratory exchange ratio (RER), and external output (W).
- Heart rate (HR), rating of perceived exertion (RPE) (Borg, 1982).

Statistics

For all variables mean scores were calculated for the last minute of each exercise bout of the pre and post test and from these scores a mean score per test was calculated for each variable. Independent t-tests were used to compare both groups at pre test. Repeated measures ANOVA was conducted to check for differences in learning effects between both groups on all outcomes ($p<0.05$).



Figure 1. A Cruiser ergometer.

Results

At pre test RER was significantly higher for the one-leg group ($p=0.01$), but other variables did not differ significantly at pre test (Table 1). At post test, the one-leg exercise group improved significantly in all important variables (GE ($p<0.01$), VO_2 ($p<0.01$), RER ($p<0.01$), HR ($p<0.01$),

and RPE (p=0.01)). The two-legs exercise group only improved significantly in RER (p=0.02) and HR (p<0.01), but not in other variables. However, for all variables no significant interaction effect between group and test was found.

Table 1. Mean scores (± standard deviation) on most important variables for both groups at pre and post test (mean of last minute of all three exercise bouts).

	Pre test		**Post test**	
	One leg	Both legs	One leg	Both legs
GE (%)	9.20 ± 0.82	10.81 ± 2.55	10.92 ± 1.70 *	12.17 ± 2.73
VO_2 (L/min)	1.29 ± 0.11	1.16 ± 0.26	1.12 ± 0.14 *	1.03 ± 0.20
RER	0.87 ± 0.04	0.82 ± 0.05	0.81 ± 0.05 *	0.80 ± 0.03 *
HR (bpm)	109.9 ± 12.8	101.5 ± 9.0	99.1 ± 5.6 *	94.1 ± 6.7 *
RPE	2.4 ± 1.0	2.0 ± 1.1	1.2 ± 0.6 *	1.4 ± 1.2

* = Significant difference between pre and post test at $p < 0.05$.

Conclusion and discussion

Adaptations in GE can be seen after a short low intensity exercise program on a combined arm-leg ergometer when only one leg is used. This finding may have important implications for the use of the Cruiser ergometer in the rehabilitation of patients with a leg amputation. It indicates that improvements in efficiency can be seen after a short low-intensity exercise program. When both legs are involved, the improvement in GE is not found. However, no significant differences in improvement in GE between exercising with one leg versus two legs have been found. This may be explained by a tendency towards improvement when two legs are involved. Further, although no significant difference in absolute GE values was evident between exercising with one or both legs, a tendency towards lower GE in exercising with one leg was found. In future research the study should be repeated with a larger sample size to investigate the differences in GE and adaptation process between combined arm-leg exercise with one versus two legs involved. Finally, since in this study only healthy subjects participated, the study should be repeated with amputation patients.

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Muscle strength is related to the one-minute walk test in young children with cerebral palsy

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Abstract The purpose of this study was to assess the relationship between muscle strength and walking performance in children with cerebral palsy (CP). 18 Ambulatory children aged 3-11 years (mean=6.5 years, SD=2.0, range 3.7-10.7) with unilateral (n=9) and bilateral (n=9) spastic CP, GMFCS I (n=11) and II (n=7) were assessed on two test occasions. At each test occasion isometric strength of the hip abductors (ABD), knee extensors (KE), ankle plantar flexors with knees flexed (SOL) and extended (Gastroc) of the most impaired limb were measured three times using a handheld dynamometer. Torque (Nm) was calculated by multiplying force (N) by the length (m) of the lever arm. The 1 minute walk test (1MWT) was performed once each test occasion. The average of the two test occasions and repetitions (of strength measurements) was used for further analysis. Regression analyses were performed. A correction was made for the possible confounder height when necessary. There was a strong association between isometric muscle strength (GSTR R^2=75%, ABD R^2=74%, SOL R^2=71%, KE R^2=59%) and the 1MWT. Height was a confounder for the relationship between the 1MWT and ABD or SOL. It can be concluded that isometric muscle strength of the lower extremities has a strong relation to the 1MWT in young children with CP.

Keywords Muscle strength, walking performance, cerebral palsy

Introduction

The ability to walk is of major concern for the families of children with CP (1). In the group of children with a spastic CP, 60 - 70 % has achieved walking ability with or without assistive mobility devices between 6 -12 years, which is level I-III according to the GMFCS (1;2). In order to walk without assistive devices, stability in the stance phase and propulsive power in the ankle are important factors. In able-bodied persons, the highest generation of power during the entire gait cycle is produced by the plantar flexor muscles during the end of push-off, which is the period between heel rise and toe off (3). In children with CP it is important to establish an optimal gait pattern within the constraints of their motor impairments (4). With the muscle weakness around the ankle, knee and hip, and the important role of these muscles in relation to gait pattern and

walking ability (3), there is a need to understand the role of muscle strength when planning interventions such as physical training, orthotic treatment, botulinum toxin treatment and orthopaedic surgery for children with CP. This especially applies to children below 7 years who are still developing their gait pattern (5). The purpose of this study was to assess the relationship between muscle strength and walking performance in children with CP.

Methods

Participants

A sample of 18 ambulatory participants (14 girls, 4 boys) in the age of 3-10 years (mean=6.5 years, SD=2.0, range 3.7-10.7), with a diagnosis of unilateral (n=9) or bilateral (n=9) spastic CP, GMFCS I (n=11) and II (n=7) were recruited from a rehabilitation centre, a special needs school for children with disabilities, and a university medical centre. The Medical Ethics Committee of the VU University Medical Center in Amsterdam approved this study and written informed consent was obtained from the parents of each participant.

Procedure and Measurements

Participants were assessed on two test occasions, within three weeks with the same conditions and time of day. The muscle strength tests were performed on both test occasions, with three repetitions on each test occasion. Isometric muscle strength was measured of the hip abductors (ABD), knee extensors (KE) and ankle plantar flexors with knee extended (Gastroc) and knee in 90 degree flexion (SOL), with a hand-held dynamometer (microFET Hand-held Dynamometer, Biometrics BV, Almere, The Netherlands). The make-method, where the child gradually builds up force against the dynamometer for about 5 s, was used. Lever arm was measured between standardized landmarks with a hard tape measure. Torque (Nm) is calculated by multiplying force (Newton) by the length (meter) of the lever arm. The 1 minute walk test (1MWT) was performed once each test occasion. The average of the two test occasions and repetitions (of strength measurements) was used for further analysis. The reliability of the measurements increases when taking the average over two test occasions (6). Regression analyses were performed. A correction was made for the possible confounder height when necessary.

Results

The strongest association between isometric muscle strength and the 1MWT was found in the Gastroc: R^2=75% (β=2.06, 95%CI=1.43-2.70, p<0.001) (Figure 1). Also strong associations were found between the isometric muscle strength of the hip ABD: R^2=74% (β=2.40, 95%CI=1.14-3.66, p=0.001); SOL: R^2=71% (β=1.51, 95%CI=0.28-2.74, p=0.02); KE: R^2=59% (β=1.02, 95%CI=0.57-1.47, p<0.001) and the 1MWT. A correction for the confounder `height` was made for the relationship between 1MWT and hip ABD and SOL.

Discussion and conclusion

The strong association between isometric muscle strength of the Gastroc, ABD and SOL and the 1MWT is in agreement with other studies that showed that plantar flexion and hip abductors muscles are most important for walking (7). The results may suggest that strength training can improve walking performance in the 1MWT. Although strength training is more commonly used in children with CP, increases in strength are not always accompanied by improvements in walking (8).

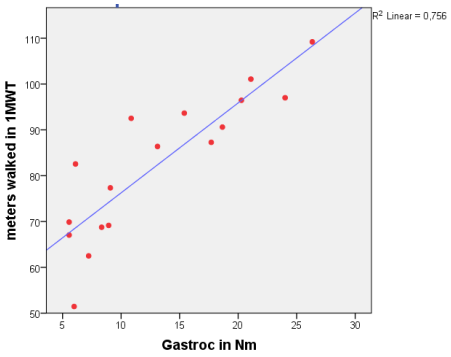

Figure 1. Scatterplot HHD ankle plantar flexor extended knee (Gastroc) with 1MWT

Application of motor learning and task-oriented exercises might be needed to transfer the increase in strength achieved in the training to functional activities such as walking. In addition the plantar flexor muscles are often not included in the strength training programs and the muscle contraction time used in the strength training programs are lower than the time that is needed in walking (9). It is concluded that isometric muscle strength of the plantar flexors and the hip abductors are strongly related to the 1MWT in young children with CP. More research is necessary to understand the role of muscle strength in relation to walking ability, with a focus on task specific, high speed training.

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Effects of ankle foot orthoses on body functions and activities; a systematic review

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Abstract *Purpose:* Ankle muscle paresis often leads to decreased mobility. To improve walking ability, many people with paretic ankle muscles use ankle foot orthoses (AFOs). However, AFOs may limit ankle range of motion (ROM) introducing additional problems in activities requiring more ROM. AFOs can have effects on body functions and on activities according to International Classification of Functioning, Disability and Health. While both domains are needed for a complete evaluation, existing reviews focused only on body functions. Gaining insight in effects of AFOs on both domains may aid in developing new orthotics and prescribing the most suitable type for an individual. This systematic review focuses on the effects of AFOs on body functions and activities in people with paretic ankle muscles. *Methods:* Studies published before January 2013 were systematically searched in PUBMED, CINAHL, EMBASE and Cochrane Library. Studies were included if effects of AFO(s) were evaluated on body functions and/or activities in patients with paretic ankle muscles. Studies solely focusing on people with spasticity were excluded. *Results:* Twenty-one studies were included. Compared to unbraced walking, polymer jointless dorsal AFOs (PAFOs) increased dorsiflexion during swing (by 5.6°) without affecting peak push-off moment (PPM) in people with dorsiflexor paresis (DF). PAFOs increased PPM during walking (to 0.9Nm/kg) in people with plantar flexor paresis (PF) and combined paresis (DPF) but not to norm values (1.2Nm/kg). Ankle ROM during walking decreased using PAFOs with PF (to 16°) and DPF (to 13°). PAFOs made walking stairs difficult. *Discussion:* PAFOs improved dorsiflexion during swing and PPM during stance. However, although PPM improved, norm PPM values are still higher. PAFOs also decreased ankle ROM which makes stair walking more difficult. Normal walking requires a minimum of 30° ROM. Walking stairs requires even more. New orthotics should therefore support ankle function and allow sufficient ankle ROM to not hamper activities.

Assessment of wheelchair-athlete interaction in wheelchair basketball

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Abstract The purpose of this study is to present the methodology for the assessment of the activities of both the athlete and the wheelchair in wheelchair basketball. In the methodology presented, arm movements of the athletes are assessed using systematic video observation related to the movement and rotation possibilities of their wheelchairs. Simultaneously trunk motion is recorded with an inertia sensor. Observational data and sensory data are combined in an activity profile. Only preliminary results from one player (field position center) during one complete match are available. The presented methodology will be used to determine differences in activity profiles between playing positions in wheelchair basketball and to study design aspects of the wheelchair that is used in wheelchair basketball.

Keywords Wheelchair basketball, physiological demands, match-analysis, activity profile

Introduction

There is limited information on the match-play demands of wheelchair basketball players. Match-analysis can be helpful in identifying the task characteristics of the sport. Essential in wheeled sports performance is knowledge about the athlete, the wheelchair and their interaction. Athletes control their wheelchairs through physical actions that cause movements of their wheelchairs (propulsion). The propulsion of the wheelchair is the result of forces exerted on the rim of the wheelchair (hand-rim contact). There are two ways of power generation: via arm-power only or by the combination of arm-power and trunk flexion. The amount of trunk flexion motion will affect the propulsion velocity (Veeger, van der Woude & Rozendal, 1989).

In this study, the methodology to observe arm and trunk movements (or in combination) of the athletes with respect to the movement and rotation possibilities of their wheelchairs during a wheelchair basketball match is described. Understanding the differences in task characteristics imposed on top-level wheelchair basketball athletes based on their field position during competitive matches (activity profile) is necessary to study design aspect of the sports wheelchair and the interaction between the wheelchair and the athlete.

Methods

Participants
Video analysis was undertaken for four matches completed as a part of the 2013-2014 Dutch national Wheelchair competition.

Process
Video recordings were made during each match using two High Definition video cameras (Casio EX-FH100, 1280*720, 20-240mm). Camera positions varied depending on venue, and were placed on a distance between 5 and 10 m from the field, at an elevation of 3-5 m from the ground.

Video footage was observed using the game-analysis system DartFish (version 7.0) to log frequency and duration of the activities.

Trunk motion is recorded with an inertia sensor (x-IMU; x-io Technologies; measuring linear acceleration, angular velocity and magnetic field orientation registration at 256Hz). The x-IMU is placed between the angulus inferior scapulae on the processus spinosus.

Observational data and sensory data are combined in the data analysis.

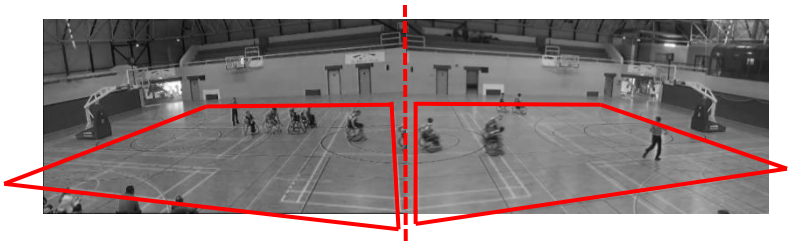

Figure 1. Overview video image for video analysis in DartFish 7.

Variables

In table 1 an overview of the different variables and the possible combination is given. For each variable frequency and duration is observed and the sequence of all the different variables. There are six possibilities in wheelchair movements; forward and backward displacement, rotation, brake, block (abrupt braking) and standing still. An athlete can control there wheelchair with arm-power (one or two hand exert force on the rim) possibly enhanced by trunk flexion (addition trunk). Wheelchair movement without arm and trunk movements is defined as idle.

Table 1. Overview variables wheelchair-athlete interaction (x= possible, -- = no possibility). In block and rotation possibilities all control options are combined.

		Wheelchair possibilities					
		Displacement forward	**Displacement backward**	**Brake**	**No movement**	**Block**	**Rotation**
Control options	**1 hand**	X	X	--	X		• Right • Left
	2 hand	X	X	X	X		
	Trunk	Addition	Addition	Addition	X		
	Idle	X	X	--	X		

Preliminary results

Based on observational data from a center player in the Dutch National Wheelchair Competition (male, 33 year) an activity profile was determined. Table 2 and 3 shows an frequency and duration overview of the wheelchair-athlete variables during a match.

Table 2. Total overview percentages wheelchair-variables in total match. Percentage based on total match (9.69% total match player not active in field).

Displacement forward(%)	Displacement backward(%)	Brake(%)	No movement (%)	Block	Rotation (%)
38.39	2.41	2.59	26.23	61 times	20.69 *Turn right: 56.44* *Turn left: 43.56*

Table 3. Total overview percentages control options athlete in total match. Percentage based on total match (9.69% total match player not active in field). Trunk data are not analyzed at the time.

	Displacement forward(%)	Displacement backward(%)	Brake(%)	No movement (%)
1 hand	0.54	1.13	--	4.71
2 hand	75.69	98.30	99.93	78.42
Remainder	22.41	0.00	0.06	15.72

Figure 1 shows the sequence of the different variables during the first five minutes of a match in the Dutch national Wheelchair competition (activity profile).

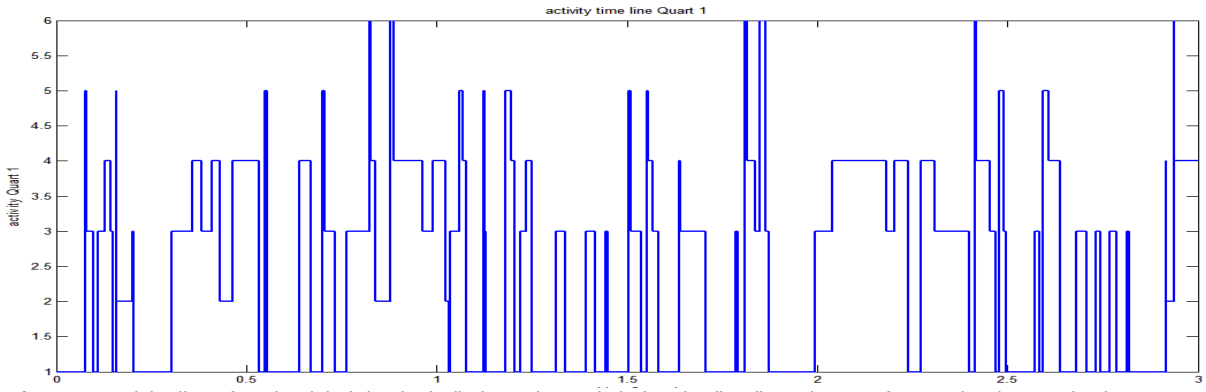

Figure 1. Activity-line of a wheelchair basketball player (center) during the first five minutes of a match. The X-axis shows duration of the match in milliseconds (x10.000), Y-axis shows activities (1=displacement forward, 2=displacement backward, 3=rotation, 4=no movement, 5=brake, 6=block).

Conclusion and discussion

The method of video analysis described is feasible and provides useful outcomes. Based on the results, a reliable activity profile can be established for wheelchair basketball athletes. Applicability is not yet determined for trunk motion data based on an inertia sensor. Regarding the feasibility, the placement of the sensor on the back of an athlete does not limit his movement possibilities. Data of the 2013-2014 Dutch national Wheelchair competition is currently being analyzed and complete results are expected in June 2014.

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Development of Aquatic Skills in a Child with Severe Intellectual and Visual Impairment

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Abstract The purpose of this descriptive case study was to analyze the development of aquatic skills of a child with severe intellectual impairment and total visual impairment. The sample was a boy of 7 years old who participated in a program of adapted motor activity (AMA). Data was collected from footages of aquatic activities developed during two and half weeks, totaling 12 sessions of one hour each. The assessment matrix of aquatic skills (WINNICK, 2004) was used throughout the intervention program implementation. The student showed positive performances in 3 categories of the proposed water skills: entering into the water, coming out of the water and guidance in the water. At the end of the interventions, it was possible to stand out as positive outcomes: understanding the entry and exit through the adapted ramp with the use of remaining senses, controlling the performance of side bearing and frontal diving with physical and verbal commands, and also, improvement on the 14 proposed skills in the category of water guidance, which is directly related to the respiratory control. Within this category, it was found an important development in the skills of blowing bubbles, shallow and deep dives. However, in the categories of propulsion and swims there were no changes in relation to the initial skills of the student. It was noted that water activities allowed the student to overcome difficulties through the numerous benefits they provide, by giving a qualitative leap in the performance of certain exercises, including the acquisition of autonomy on special skills. Thus, it is concluded that water activities generate more adequate physical conditioning enabling a better quality of life for its practitioners if they are structured to meet the specific characteristics of each person.

Keywords Adapted motor activity, Aquatic skills, Intellectual impairment, Visual impairment.

Introduction

The water activities are an important instrument of implementation to the Physical Education because they allow children to start an organized learning (Borges et al. 2008). This happens because the motivational aspects and therapeutic properties of the water stimulate the development, cognitive learning and concentration power since the learner tries to understand the movement of his own body by exploring various ways of moving, and adapting his possibilities to the water properties (Lèpore et al. 1999). The objective of this research was to analyze changes, in the development of aquatic skills, of a child with severe intellectual and visual impairment.

Methods

This qualitative, descriptive and case study-type research involved the following steps: pre-assessment, intervention and post-assessment of aquatic skills. Data were collected from footages and field notes of the classes. The matrix of aquatic skills (Winnick, 2004) considered

the categories of water orientation, front propulsion, back propulsion, entrances and exits. It was approved by the Ethics Committee of the Federal University of Santa Catarina under the no. 911/2010.

The participant was a seven-year old boy with total visual impairment and severe intellectual impairment. The interventions were performed in an adapted swimming pool (12.5 x 17m), heated (from 290 to 320 C), equipped with ramps, access steps and grab bars. The aquatic activities were conducted in 12 sessions, in a sequence of two weeks and a half, and excluding the weekends. The lessons were planned and organized, in advance, by following the skills of the analysis matrix, and lasted one hour. Every aquatic activity proposed to the student received a score code: O (cannot do), X (independent), V (verbal commands), F (physical commands). It is noteworthy that the skills of the categories "lateral propulsion" and "breaststroke" were not evaluated.

Results

In the category entrances, the student presented some changes in the skills related to *entrance through the access ramp*, *lateral rolling* and *front dive*. Concerning the ability *entrance by the ramp*, he understood and learned the entrance way to the swimming pool because, during the classes, he began to clash less in the lateral bars, and in the mobile support bars of the entrance ramp. In the *lateral rolling*, he understood the skill and could develop it from verbal and physical commands. The ability of *front diving* was developed independently in two classes; however, it was possible to note that the student was not prepared to do it alone. In the category exits, he began to recognize the environment (adapted ramp), during the classes, by using the remaining senses, especially the tact.

The student showed positive results in all the skills related to the water orientation category. From the first lesson, he independently developed the following skills: *wash your face, put your chin into the water, put water in your mouth, put your mouth and nose in the water, put your face in water, put the whole body into the water, blow bubbles and blow bubbles with your face in the water*. There was an improvement in the performance of skills like *blowing bubbles, lying on front with the face into the water, blowing bubbles under the water with all the body under the water*, going from the need for verbal and physical help to his independence to do them.

The understanding and correct implementation of the respiratory mechanism was the main student’s evolution. Besides contributing to the water fluctuation, there were improvements in the following skills: *to sink, exhale the air and climb to the surface*, which were developed independently. In the abilities of *sinking, exhaling and rising 5 times in the shallow part*, he passed from the need of verbal and physical commands to his independence. In the ability of *sinking, exhaling and rising 10 times in the shallow part*, he required less physical commands. In relation to the same skills in the deep area of the swimming pool, it was possible to provide physical commands until the end of the interventions due to the student’s dependence in that location. In these skills, it was noted that the apnea increased during the classes. There was no improvement in the category frontal swimming propulsion, and it was noted that the child's difficulties, in these skills, were more related to the understanding of commands than the execution of activities. The student showed changes in one skill in the category back propulsion *(floating on his back – 5 seconds)* and developed it from verbal and physical commands in five out of twelve classes.

Conclusion and discussion

The student had the best results in the category guidance into the water. The good adaptation of the student, in the liquid medium, from the beginning of the interventions favored the learning and performance of such skills, and for Lima and Almeida (2008) this provides the opportunity to live fundamental and proprioceptive experiences for the structuring of body awareness and motor control, in a child with DV.

It is possible to highlight the respiratory domain as another factor that influenced all the skills learned and improved since the student cannot learn technical movements before mastering the breathing mechanism (Pérez, 2006). This improvement helped to avoid the rapid fatigue and allowed to stay more time in the activities, throughout the lessons.

It was found that the proximity and physical controls were necessary to stimulate the remaining senses. In this case, the sense of touching was the most used resource for instructions/demonstrations. Therefore, the physical and emotional contact between teacher and student was very important to the progress in aquatic skills. The use of materials, which were particularly vital in the investigation of aquatic skills (Stopka, 2001), were also a means used to minimize the difficulties related to the lack of vision and understanding. With the use of this resource along with physical commands, the child acquired more confidence and became more independent, in the aquatic environment.

It is concluded that water activities through the numerous benefits they provide, allowed the student to overcome his difficulties by giving a qualitative leap in the development of aquatic skills, including his independence in acquiring special skills. Thus, it can be said that the student achieved successfully the first step for learning aquatic skills since the domain of basic skills is the starting point for new learning (Borges et al. 2008).

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Poster presentations
Friday, April 25, 2014

Load Distribution in a Throwing Frame Seat of Paralympic Sports

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Abstract The aim of this research was to evaluate the load distribution on the throwing frame seat of paralympic sports. The reference load distribution was taken in an adjustable backrest and seat system (wheelchair ergometer) and compared to the load distribution on the throwing frame seat. The main goal was to assess how the low adaptability of the throwing frame seat can affect the load distribution. This study was approved by the ethics committee for research Conep (protocol 315/07).The sample comprised of seven shot put athletes. All research participants signed a consent form. The load distribution was evaluated in the seated position by the Force Sensing Resistor pressure mapping system. The system was placed on the wheelchair ergometer seat developed at the Habilitation/Rehabilitation Center in Paralympic Sports (NH/RESP) and adjusted to the anthropometric measurements of each athlete. The measurement system was positioned on the throwing frame seat to get the load distribution in the throw seated posture. The load distribution on the throwing frame seat showed a mean load of 0,56 N $\pm$ 0,63, while in the wheelchair ergometer it had a mean load value of 1,5 N $\pm$ 0,52. Increased load distribution values were observed when the ergonomic adjustments were performed according to the anthropometric measurements of the participants. When compared to the throwing frame, the wheelchair ergometer improved load distribution at the support base (seated posture) when fit to the individual measurements of the athletes. The customization of the throwing frame should focus its attention to individual anthropometric features in order to provide a better load distribution on the seat and thus optimize stability, functionality, comfort sensation and performance of the athlete.

Keywords Throwing frame seat, Paralympic sports, Disabilities, Shot Put

Introduction

It is known that the benefits of adapted sports go beyond the maintenance and improvement of a healthy physical condition. This important tool influences the mental health and quality of life for disabled people (Blauwet, Willick, 2012). The development of new assistive technologies, providing increased functionality of the individuals, implies the optimization to perform activities of daily life and also allow more effective action in tournaments (Burkett, 2010). The throwing frame used in athletics field events aims to contribute to bear the weight of athletes with restricted mobility. Currently, the design of these devices is based on a qualitative approach, taking into account the coach planning, the equipment functionality and comfort. The relationships between athletic performance and the characteristics of the throwing frame have received little attention so far. Clearly, there is the need for studies that investigate the relationships between performance and the design of this device used in the shot put modality (Frossard, *et. al*., 2012).

The objective of this study was to evaluate the load distribution on the throwing frame seat and compare it to the distribution in the wheelchair ergometer adjusted to the anthropometric measurements of each participant, checking if the absence of these adjustments can modify the load distribution.

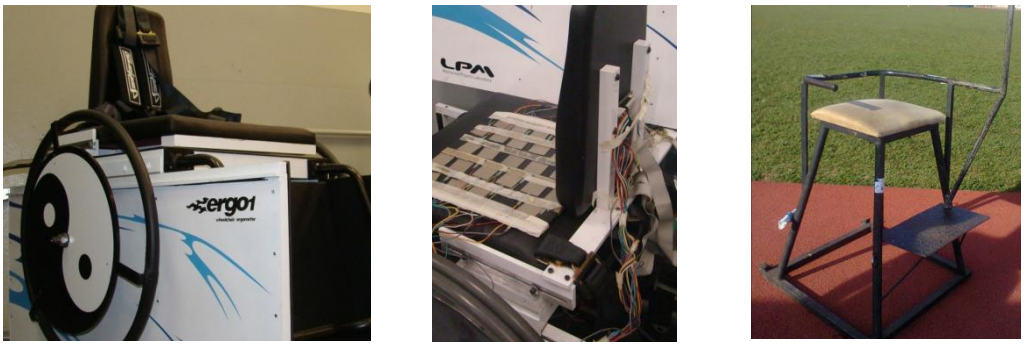
Methods

Participants

Seven athletes of the shot put modality at the Center for Athletic Training SESI Uberlândia, Brazil (CTA / SESI / MG), categories F33, F34 and F56 were evaluated. Initially, the following individual anthropometric measurements were recorded: distance between popliteal angle and feet base and the distance between the popliteal angle and posterior part of the buttocks. The work was approved by the ethics committee for research Conep (protocol 315/07).

Assessment and devices

The wheelchair ergometer was developed by the Habilitation/Rehabilitation Center in Paralympic Sports (NH/RESP) and used in association with the Force Sensing Resistor pressure mapping system., The same system was used on the throwing frame seat. The data acquisition, processing and visualization of results were performed by the FSR system software (Figure 1).



(A) (B) (C)

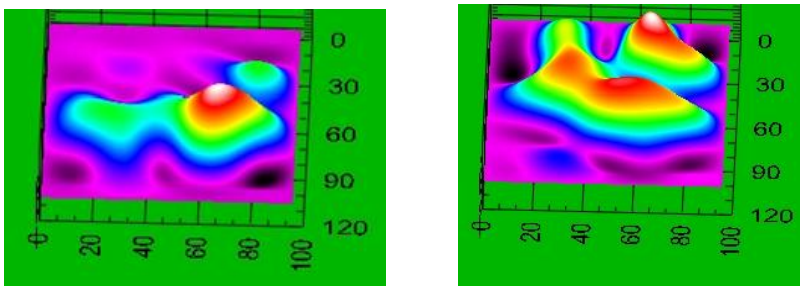
Figure 1. (A) Wheelchair ergometer (B) Force Sensing Resistor pressure mapping system placed on the wheelchair ergometer seat (C) throwing frame.

Statistics

The results were analyzed using descriptive and inferential statistics. SPSS software, version 19.1., was used to describe the quantitative variables in terms of mean and standard deviation. The correlation between the load distribution for the two seats was verified through paired t-test using the significance level of 5% ($p<0:05$).

Results

The sample consisted of three female and four male participants, mean age was 30.71 ± 12.09 years and mean weight 68.28 ± 23.16 kg. All participants are athletes of the shot put modality, and 70% belong to the functional class F56. Figure 2 shows the behavior of athlete number five (A5) load distribution on the throwing frame and on the wheelchair ergometer.



(A) (B)

Figure 2. (A) surface curves in throwing frame (B) surface curves in wheelchair ergometer.

This figure is representative of approximately 85% of the load distributions in the studied sample. The load distribution on the throwing frame was concentrated on a smaller area compared to the weight distribution on the wheelchair ergometer. Pressure peaks were detected in both situations. However, on the ergometer seat they occurred to greater extent, especially on the ischial region. There was also a greater , weight concentration on this region bearing on the throwing frame.

Statistical analysis of the load distribution on the throwing frame pointed to an average of 0.56 ±0.63 N, while the average value on the wheelchair ergometer was 1.5±0.52 N. Comparisons for the averages ($p = 0.068$) were performed by the t-test.

Conclusion and discussion

The results were not statistically significant. However, the presence of a larger area of load distribution on the wheelchair ergometer shows a greater contact surface and consequent higher stability of the sitting posture with the personalized adjustments of the equipment. The pressure mapping proved to be a useful tool in the assessment of posture. Further studies are needed for a dynamic evaluation of the shot put that correlates the sitting posture and the athlete's performance.

Acknowledgements

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ReSpAct: a dose-response study into a person-tailored physical activity and sports stimulation program for patients

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Abstract *Background and purpose:* 'Rehabilitation, Sports and Exercise' (RSE) is a person-tailored physical activity and sports stimulation (PASS) program, based on motivational interviewing (MI). The program aims to promote an active lifestyle in persons with a physical disability and/or chronic disease subsequent to their rehabilitation period. Offering a post-rehabilitation PASS program has proven to be effective in improving daily physical activity behavior and sport participation. However, evidence for dose-response associations is lacking. Therefore, the study aims to devise a conceptual framework and compose a questionnaire for examining the dose-response associations and the underlying determinants of the RSE program. *Methods:* Based on a semi-structured literature review a set of possible determinants of the program outcome, both at program-level and individual level, was extracted from literature. Then a conceptual framework has been devised. Based on that a questionnaire was designed for testing the framework in a broad patient population that participates in the RSE program. *Results:* The conceptual framework shows the relationship between the dose of the program, reflected in e.g. use of MI, working alliance and total contact time between counsellor and patient, and outcome measures. This relation is influenced by several determinants, both on the level of individual users (e.g. motivation, attitude, health status) and on environmental level (e.g. social influence). *Conclusion:* The next step is to test the devised conceptual framework by asking participants of the RSE program to fill out the developed questionnaire. This is done in the nationwide, longitudinal survey-study 'Rehabilitation, Sports and Active lifestyle' (ReSpAct). This study will be conducted within 12 rehabilitation centers and 6 hospitals in the Netherlands. 2000 in-patients and out-patients (≥18years) will be included between April 2013 and December 2015.

Keywords rehabilitation, sports, exercise, behavioral change, counseling, inpatients, outpatients

Introduction

There is an increase in people with disability and chronic disease and these persons are on average more inactive compared to the general population (Geidl, Semrau et al. 2014). Especially, people who have participated in a rehabilitation program are likely to adopt a sedentary lifestyle just after the rehabilitation period, despite the relatively high physical activity status during their rehabilitation program (Van der Ploeg 2005). From a former RCT study it can be concluded that offering a physical activity and sports stimulation (PASS) program directly following the rehabilitation period is effective in establishing a behavioral change and structurally improving daily physical activity behavior and sport participation, in both the short term and up to one year after discharge of rehabilitation. Approaching persons in each stage of behavioral change in a stage-specific way, when focusing on the promotion of behavioral change, appears effective. Based on the results of the evaluated PASS program in this RCT study, the program has been further developed in the new PASS program called 'Rehabilitation, Sports and Exercise' (RSE, Dutch: Revalidatie, Sport en Bewegen). An important new feature of the program RSE is the use of motivational interviewing (MI; Miller and Rollnick, 2013) in supporting the patients.

RSE is a person-tailored PASS program which aims to promote an active lifestyle in persons with a physical disability and/or chronic disease. During the rehabilitation period, the RSE program focuses on structurally providing sports and exercise activities and encouraging the patient to make physical activities as an ongoing part of their lives. In addition, the patient receives a face-to-face conversation and four telephone counseling conversations with a sports consultant as part of the RSE program. All conversations are individually, based on MI and aimed to provide personal advice and to support the patient in picking up or maintaining an active lifestyle.

Despite the current evidence that a PASS program is effective in improving daily physical activity behavior and sport participation in patients, evidence for dose-response associations is lacking and thus knowledge about who will benefit from it most (Mant 1999). In order to be able to offer the RSE program in a more efficient way for nested cohorts of patients, insight in these associations and the underlying mechanisms of the RSE program are needed. This study aims to devise a conceptual framework which encompasses important dose-response components and determinants from literature of PASS programs based on theories of behavioral change. This will provide insight in the extent to which the current RSE program fits literature and will be helpful in examining the dose-response associations and the underlying determinants of the RSE program. Based on that comparison, a questionnaire will be composed in order to scientifically evaluate the RSE program.

Methods

Based on the content of the existing RSE program, the authors identified the dose components and main outcomes of the program. Then a semi-structured literature review of Pubmed, supplemented by references lists and authors knowledge, was executed in order to identify the determinants of physical activity behavior in people with a physical disability and/or chronic disease. Studies included were: 1) intervention studies targeted physical activity (PA) behavior change in adults which reported the PA behavior outcomes; 2) intervention studies targeted PA behavior change in adults with counselling as the method of intervention delivery; 3) studies and reviews on theories of behavioral change, motivation and the relationship between patient and treatment provider. The Physical Activity for people with a Disability (PAD) model (Van der Ploeg 2005) was the starting point in identifying the main factors in behavioral determination.

Results

Based on the identified main dose components of the RSE program and the set of possible determinants of the program outcome, a conceptual framework has been devised (figure 1). The framework shows several possible dose-response associations, which are expected to be influenced by several immutable and modifiable determinants. The dose of the program (i.e. exposure or amount of program delivered) is reflected in e.g. use of MI and total contact time between sports consultant and patient. Determinants (i.e. factors that have causal associations with the outcome) are both on the level of individual users (e.g. motivation, attitude, health condition) and on environmental level (e.g. context of rehabilitation and social influence).

Based on the devised framework a questionnaire was designed for scientifically evaluating the RSE program, which takes into account the components and determinants that are expected on which the existing program RSE intervenes (figure 1). The questionnaire includes a selected set of validated questionnaires as well as new instruments that will be evaluated in the course of data collection and data analysis.

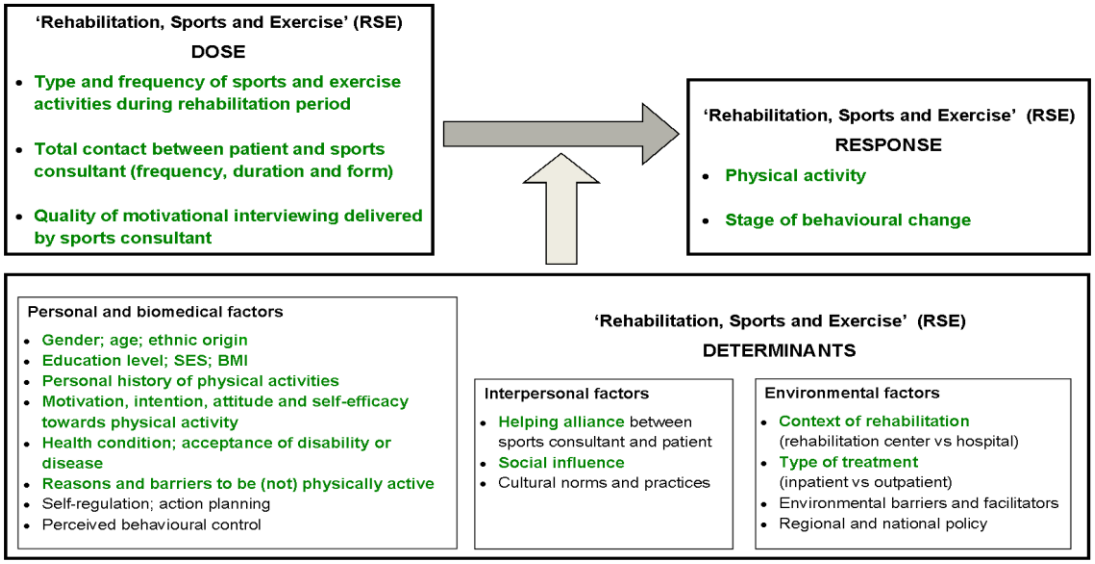

Figure 1. Conceptual framework of the dose-response associations of the physical activity and sports stimulation (PASS) program 'Rehabilitation, Sports and Exercise'. The green shaded components and determinants are surveyed in the questionnaire. SES = socioeconomic status; BMI = body mass index.

Conclusion and discussion

A conceptual framework has been devised which encompasses important dose-response associations and determinants from literature. After comparing the conceptual framework with the existing RSE program, a questionnaire has been composed for scientifically evaluating the current RSE program. For that purpose, participants of the RSE program will be asked to fill out the developed questionnaire. This is done in the nationwide, longitudinal Dutch survey-study 'Rehabilitation, Sports and Active lifestyle' (ReSpAct, www.respact.nl). This study will be conducted within 12 rehabilitation centers and 6 hospitals in the Netherlands. 2000 in-patients and out-patients (≥18years) will be included between April 2013 and December 2015.

Acknowledgements

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The use of concentration, stress management, and emotions management by elite athletes with disabilities

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Abstract The importance of psychological skills training programs in the improvement of sports performance is widely recognized. However, research about how athletes with disabilities develop concentration, stress management, and emotions management skills is quite scant. Therefore, it was our aim to explore the use of use of concentration, stress management, and emotions management, in both competition and practice settings, by elite athletes with disabilities. Fourteen Portuguese athletes (12 males and 2 females) with visual impairment (n=5) and physical disability (n=9) comprised the sample. All the athletes were included in the Paralympic Project London 2012. Semi-structured interviews were conducted and analysed using content analysis and standard qualitative methodology. All participants were unanimous to acknowledge the importance of concentration for performance, and most of them considered themselves to be successful in the use of this skill. Regarding stress management and emotions management, athletes mentioned both successful and unsuccessful relationships with performance and identified several factors that may damage their sport outcomes, mainly in competition setting. Our findings also suggested that the use of psychological skills in practice setting is clearly neglected. Although only elite athletes were analysed in this study and most of them referred having a successful psychological ability in the different skills analysed, it was also evident that there was a lack of psychological support and the need to improve the use of psychological strategies. Frequently, athletes use their own personal strategies to face psychological adverse situations in the competition setting.

Keywords psychological skills, elite, disability sport

Introduction

The psychological skills are a group of cognitive, emotional, and behavioural strategies that both athletes and coaches have to acknowledge and apply to achieve the optimal psychological state in the training and competition setting (Gould et al., 2009). Therefore, the purpose of this qualitative research was to study in-depth the knowledge about the use of concentration, stress

management, and emotions management by elite athletes with disabilities. Simultaneously, the use of those skills in competition and training settings was examined.

Methods

Fourteen athletes (12 males and 2 females) with visual impairment (n=5) and physical disability (n=9) comprised the sample. The participants' ages ranged from 17 to 40 years (M=29.4yrs; SD=6.5yrs). All the athletes had international experience and most of them (93%) were medaled in former Paralympic Games or World and European Championships. The sample was included in the Portuguese Paralympic Project London 2012 and represented the four Paralympic sports (boccia, n=3; swimming, n=5; track and field, n=5; rowing, n=1). The data were collected from a semi-structured interview with open-ended questions organized in accordance with the research questions of the study. The recommendation of Patton (2002) for the inductive-deductive content analysis was used for data analysis.

Results

Concentration

All athletes mentioned the importance of concentration to perform in training and competition. Different situations were raised about the importance of concentration according to the type of sport/task (e.g., sprinter versus long courses races) and the type of disability (e.g., visual impairment). All the athletes were unanimous in considering that they were able to concentrate successfully during competitions and only three athletes mentioned that during training they were not successfully concentrating. Two athletes with visual impairment identified three external distractors (e.g., collision with other persons, lack of coordination with the athlete-guide, and bad weather conditions) specifically related with their type of disability.

Stress management

Relation with performance was divided in successful and unsuccessful relation. Stressors were related with the sources of stress, demands that performers may have to deal with in stressful situations. Level of fitness (e.g., poor fitness), intra and interpersonal expectation (e.g., self-responsibility), opponent comparison (e.g., sport classification), and environmental conditions (e.g., waiting to compete) were sources of stress identified in the competition setting.

Emotions Management

Eleven athletes explained that they successfully cope with emotions in the competition setting. Four of them considered themselves to be positive persons and maintained that attitude in sport. However, a considerable number of athletes (n=10) mentioned an unsuccessful ability to cope with emotion, particularly in the training setting (n=7). Relationship with the coach (n=1), extremely demanding training (n=4), conflicts with the athlete-guide (n=1), and general life concerns (n=2) were reasons mentioned in the training setting.

When analysing the three psychological skills there was a clear difference between the use of psychological skills and strategies between competition and training setting. None of the athletes mentioned the use of psychological strategies in training setting to improve their concentration, stress management, or emotions management and, in some cases, athletes simply do not use psychological methods nor in training or competition setting.

Conclusion and discussion

Although only elite athletes were analysed in this study and most of them referred having a successful psychological ability in the different skills analysed, it was also evident that there was a lack of psychological support and the need to improve the use of psychological strategies. Our findings suggested that there is no systematized training to support the psychological preparation of the athletes and no practice routines to approach competition.

Acknowledgements

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Ankle foot orthoses for a kite surfer

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Abstract *Purpose:* The aim of this study was to develop ankle foot orthoses for a man with hereditary motor and sensory neuropathy (HMSN), who wants to kite surf on a strapless directional board. *Methods:* An analysis of the possible joint movements of the patient was made in a clinical setting, together with an analysis of his current orthoses. A movement analysis of kite surfing on a directional board with straps was made with a camera mounted on the board in three conditions: 1. with a subject without HMSN; 2. with a subject with HMSN without orthoses; 3. with a subject with HMSN with his current orthoses. The surfing course was registered with gps mounted on his upper arm. A biomechanical analysis was made in order to estimate the forces on the orthosis. An iterative design cyclus was followed which resulted in different prototypes and a final design for the new orthoses. *Results:* The main requirements on the orthosis were that they should compensate for the dorsal flexion paresis, they should allow 5 degrees of bending towards plantar flexion and they must be suitable for kite surfing without straps. Three prototypes were made and tested. The final design consisted of a shortened sole, a heel lift in combination with a carbon spring which forces the lower leg in a position of dorsal flexion. *Conclusion:* The third prototype was tested in the lab and on the water. Freedom of movement and stability were enhanced. The man was able to kitesurf on a strapless directional board. Definitive orthoses were made according to the definitive design.

Keywords kite surfing, orthoses, HMSN

Introduction

Hereditary motor and sensory neuropathy (HMSN) is a disorder in which one or more components of the peripheral autonomic or cranial/spinal system is damaged. In this disorder a patient experiences progressive muscular atrophy and sensory neuropathy of the extremities (Houlden et al, 2004). The subject of this study is a 29 yr old man with HMSN, who is very sportive and kite surfs regularly on a twin tip board with foot straps, while using ankle foot orthoses. This man prefers to kite surf on a strapless directional board, but in order to make this possible new ankle foot orthoses (AFO's) will have to be developed. Therefore, the aim of this study was to develop AFO's for a man with HMSN who wants to kite surf on a strapless directional board.

Methods

In order to formulate the requirements for the new AFO's, different aspects of the problem had to be analyzed. First an analysis of the possible joint movements of the subject was made in a clinical setting. Second, an analysis of his current orthoses was performed. Third, a video

analysis of kite surfing with a strapless directional board was made in 3 different ways: kite surfing of 1) a person without HMSN; 2) the subject without AFO's 3) the subject with AFO's. To get knowledge of the forces induced on the orthoses, a 2D static force analysis was made.
From these analyses product requirements were formulated and an iterative design process was started. Different prototypes were made and tested in the lab and on the water. Also the subject was asked to give his opinion (rate 1-10) about the prototypes (fit, pressure points, support, contact board, put on, design, overall opinion).

Results

From the analysis of the subject and his condition, the main symptoms were formulated. The subject has a paresis of the dorsal flectors, decreased strength of the plantar flectors, a varus position of the foot, a pes cavus, claw toes and points of pressure on the metatarsus V. His current AFO's are worn with thick socks. With these AFO's he can surf on a twin tip board while securing his feet in straps. On a strapless directional board contact between the board and the soles of his feet is needed to adequately position the feet and feel the impact on the board. Also, this contact must have a great friction resistance. The video analyses in 3 ways also resulted in product requirements: 1) every course must be surfed; 2) the blows of the water must me absorbed by the legs 3) the AFO's must compensate for the paresis of the dorsal flectors. The force analysis resulted in an estimation of the maximal static force.

In summary, the most important requirements of the AFO's:

- must compensate for the dorsal flector paresis
- must compensate for a lack of dorsiflexion mobility
- must bend up to 5 degrees towards plantar flexion for absorbing the blows of the water
- must put on with one hand
- must be used in (salt) water and sand
- no pressure points
- must have a heel lift, to compensate for a lack of dorsiflexion mobility and to change the position of the lower leg
- the static torque on the AFO must not exceed 54 Nm

Three prototypes were made and tested. The third prototype was tested in the lab and on the water. Freedom of movement and stability were enhanced. The man was able to kitesurf on a strapless directional board. The subject's opinion about the final prototype was rated 4 for fit, 5 for pressure points, 7 for support, 7 for contact board, 7 for put on, 1 for design and 7 for overall opinion, all better than his current AFO's.
After testing the third prototype, improvements had to be made on the posterior leaf spring, the fitting and the shackles of the orthoses. Definite orthoses (figure 1) consisted of two carbon shelves suited around the foot and calf that are joint by a posterior carbon leaf spring, a shortened sole to allow contact between toes and the strapless directional board and a heel lift to compensate for the lack of dorsiflexion mobility in the ankle. This total configuration is tilted forward to allow the subject to control the board from his knees rather than from his ankles.



Figure 2. Carbon Ankle 7 leaf spring from Otto Bock and definitive orthoses

Conclusion and discussion

With the new orthoses freedom of movement and stability were enhanced. The man was able to kitesurf on a strapless directional board. Because of the complexity of the movements involved in kitesurfing, some simplifications in the analysis of the movements had to be made. It would be worthwhile to further investigate the movement of kite surfing in 3D. The posterior carbon leaf spring used in the product was a 17CF1 Carbon Ankle 7 from Otto Bock. The stiffness of this spring was determined based on the kite surfer's body weight and the expected impact level during kitesurfing. Whether the chosen spring stiffness is adequate to allow 5° of plantar flexion will have to be examined in practice. The EVO's will be tested in the upcoming months.

Acknowledgements

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Running with minimalist shoes increases plantar pressure in the forefoot region of healthy female runners

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Abstract *Objectives*: Minimalist running shoes have been proposed as an alternative to barefoot running. However, several studies have reported cases of forefoot stress fractures after switching from standard to minimalist shoes. Therefore, the aim of the current study was to investigate the differences in plantar pressure in the forefoot region between running on minimalist shoes and running on standard shoes in healthy female runners during overground running. *Design*: Randomized crossover design. *Methods:* In-shoe plantar pressure measurements were recorded from eighteen healthy female runners. Peak pressure, maximum mean pressure, pressure time integral and instant of peak pressure were assessed for seven foot areas. Force time integral, stride time, stance time, swing time, shoe comfort and landing type were assessed for both shoe types. A linear mixed model was used to analyze the data. *Results*: Peak pressure and maximum mean pressure were higher in the medial forefoot (respectively 13.5% and 7.46%), central forefoot (respectively 37.5% and 29.2%) and lateral forefoot (respectively 37.9% and 20.4%) for the minimalist shoe condition. Stance time was reduced with 3.81%. No relevant differences in shoe comfort or landing strategy were found. *Conclusion*: Running with minimalist shoes increased plantar pressure without a change in landing pattern. This increased pressure in the forefoot region might play a role in the occurrence of metatarsal stress fractures in runners who switched to minimalist shoes and warrants caution in sudden use of minimalist shoes.

Keywords overuse injury, footwear, barefoot running, stress fracture, landing strategy

Introduction

Minimalist running shoes have been developed to mimic barefoot running, while at the same time offering protection to the feet (Squadrone & Galozzi, 2009). However, the use of minimalist running shoes might also cause injuries. In three recent studies authors have reported several cases of metatarsal stress fractures after a switch from standard running shoes to minimalist running shoes, possibly due to accumulation of micro traumas to the metatarsals (Cauthon,

Langer & Conigione, 2013; Giuliani et al., 2011; Salzler et al., 2012) These micro traumas might be caused by a higher pressure in the metatarsal region for minimalist compared with standard shoes (Cauthon, Langer & Coniglione, 2013).

Therefore the aim of the current study was to investigate the difference in plantar pressure in the forefoot region between running on minimalist and standard running shoes in healthy female runners during overground running. It is hypothesized that running with minimalist running shoes increases plantar pressure in the forefoot region.

Methods

Participants and design

Eighteen experienced female endurance runners participated in this study. Plantar pressure data was assessed for minimalist running shoes (Merrell™ Pace Glove) and standard running shoes (Dutchy™), according to a randomized crossover design. In-shoe plantar pressure was measured with wireless flexible insoles (Pedar-X® system; Novel Inc; Munich, Germany). All measurements were performed on a 22 meter long runway (overground running). Running speed was maintained within ± 5% of participant's comfortable running speed.

Variables

Peak pressure (PP, kPa), maximum mean pressure (MMP, kPa), pressure time integral (PTI, kPa·s) and instant of peak pressure (IPP, % of roll off) were studied for 7 anatomical regions. These regions included heel, midfoot, medial forefoot, central forefoot, lateral forefoot, digit 1, and digit 2 – 5. The main outcomes were PP, MMP and PTI for the three forefoot regions. Also, stance time (ms), swing time (ms), stride time (ms), running speed (m/s) and shoe comfort (mm on a visual analogue scale) were measured. In addition, the location of the center of pressure in anterior-posterior direction (mm) at initial contact was measured and normalized to insole length (%). This parameter (CoP-AP, %) was used as a continuous variable for landing strategy which was used to compare differences between the two shoe conditions.

Statistics

Descriptive statistics were used to describe the population characteristics. The outcome variables were analyzed separately using a linear mixed model as the main analysis of estimating the shoe effect. Participants were treated as random effect in the model and type III tests were used to determine the effects of shoe.

Results

Eighteen female endurance runners participated in this study (mean age 23.6 ± 3 years of age). The mean and 95% confidence intervals for the outcome variables and the result of the statistical comparison between the standard and minimalist running shoe are presented in table 1.

PP, MMP and PTI all increased in the medial, central and lateral forefoot with the minimalist shoe compared to the standard shoe. FTI increased for the minimalist shoe condition. For IPP, CoP-AP, shoe comfort and speed no differences between the two shoe conditions were found. Furthermore, stance time decreased with 3.8% when wearing minimalist running shoes, but swing and stride time did not show relevant differences.

Table 1. Comparison of the mean results [95% confidence interval] of the main outcome variables, landing pattern and step-time parameters.

Variable	Minimalist shoe	Standard shoe	Difference	Percentage difference	P-value
Peak pressure (kPa)					
Medial forefoot	416 [367; 464]	359 [311; 408]	56.3 [19.0; 93.7]	13.5	0.006
Central forefoot	464 [413; 515]	291 [241; 342]	173 [137; 208]	37.3	<0.001
Lateral forefoot	401 [355; 446]	249 [203; 294]	152 [110; 194]	37.9	<0.001
Maximum mean pressure (kPa)					
Medial forefoot	248 [227; 269]	229 [208; 251]	18.5 [3.05; 33.9]	7.46	0.022
Central forefoot	296 [269; 323]	209 [182; 236]	86.3 [72.9; 99.7]	29.2	<0.001
Lateral forefoot	211 [190; 233]	168 [147; 190]	43.0 [27.4; 58.6]	20.4	<0.001
Pressure time integral (kPa·s)					
Medial forefoot	54.0 [48.6; 59.4]	46.1 [40.7; 51.4]	7.95 [4.01; 11.9]	17.2	<0.001
Central forefoot	61.6 [55.4; 67.7]	38.6 [32.4; 44.7]	23.0 [18.0; 28.0]	59.6	<0.001
Lateral forefoot	55.2 [49.4; 61.1]	36.3 [30.5; 42.2]	18.9 [14.2; 23.5]	52.1	<0.001
Instant of peak pressure (% of roll off)					
Medial forefoot	55.1 [51.7; 58.6]	56.8 [53.4; 60.3]	-1.70 [-4.47; 1.07]	2.99	0.211
Central forefoot	55.4 [53.7; 57.0]	54.8 [53.2; 56.5]	0.539 [-0.853; 1.93]	9.03	0.424
Lateral forefoot	50.6 [46.1; 55.2]	50.8 [46.2; 55.3]	-0.150 [-4.55; 4.25]	0.20	0.943
Force time integral (N·s)	243 [224; 261]	237 [218; 256]	6.22 [1.08; 11.4]	2.62	0.021
CoP-AP (%)	35.7 [26.3; 45.2]	37.2 [27.7; 46.6]	-1.44 [-14.9; 12.0]	3.87	0.824
Stance (ms)	238 [222; 254]	247 [231; 264]	-9.37 [-15.6; -3.11]	3.81	0.006
Swing (ms)	483 [455; 511]	501 [473; 529]	-18.2 [-52.3; 16.0]	3.63	0.276
Stride (ms)	720 [692; 749]	748 [719; 777]	-27.5 [-64.9; 9.88]	3.68	0.138
Shoe comfort (mm)	61.5 [51.0; 72.0]	71.7 [61.2; 82.2]	-10.2 [-22.8; 2.36]	14.2	0.104
Speed	3.38 [3.14; 3.63]	3.41 [3.17; 3.65]	-0.0241 [-.0101; 0.0526]	0.60	0.515

Conclusion

The current study provides insight into the difference in plantar pressure in the forefoot region between running on minimalist and standard running shoes. The results show that running with minimalist running shoes increases the plantar pressure in the forefoot region without changing the landing pattern. This increased pressure in the forefoot region might play a role in the occurrence of metatarsal stress fractures in runners who switched to minimalist shoes and warrants caution in sudden use of minimalist running shoes.

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Factors to consider when improving participation in physical activity in youth with spina bifida

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Abstract *Purpose:* Background: Many children with spina bifida (SB) show decreased levels of physical activity (PA) despite the obvious health benefits. Earlier studies have shown benefits of training, but maintaining adequate PA seems difficult. Therefore, the first step in the development of an intervention aimed at improving PA in youth with SB, is to identify factors for participation in PA. Objective: To describe the perceived factors for participation in PA in youth (and their parents) with SB. *Methods:* Design: Descriptive qualitative research, with a thematic analysis. Eleven semi-structured interviews with parents (n=13) from young children with SB (age 4-7 years), nine focus groups with youth (n=33) with SB (age 8-18 years) and eight focus groups with their parents (n= 31) were conducted, recorded and transcribed verbatim. Two independent researchers analyzed the data. Central themes for factors for PA were constructed, using the model for Physical Activity for Persons with a Disability (PAD model) as a background scheme. *Results:* Redundancy was reached. Data showed that youth with SB encountered both personal and environmental factors for participation in PA on all levels of the PAD model. Bowel and bladder care, the competence in skills, sufficient fitness and self-efficacy were important personal factors. Important environmental factors were the contact with and support from people, the use of assistive devices for mobility and care, information transfer and accessibility of playgrounds and sports facilities. *Conclusion:* Our findings suggest that negative factors should be addressed when setting up intervention programs. But even more, turning the positive factors to account seem to be an important starting-point in improving PA in youth with SB. These positive factors, for example self-confidence and wheelchair skills, should be implemented in an intervention program.

The Groningen Meander Walking Test: a dynamic walking test for older adults with dementia

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Abstract Current tests that measure walking abilities rely strongly on healthy cognitive and physical functions. However, these functions are impaired in patients with dementia. Therefore, specifically for patients with dementia, the Groningen Meander Walking Test (GMWT) was developed. The aim of the GMWT is to measure dynamic walking ability by walking over a six meter meandering curved line, with an emphasis on walking speed and stepping accuracy. The purpose of this study was to investigate the feasibility, test-retest reliability, and minimal detectable change (MDC) of the GMWT. A repeated measures design was used with one week between the measures. Forty-two subjects with dementia participated (mean age ± SD = 87 ± 5 years; 21% male; mean mini-mental status examination ± SD = 17 ± 4). Adherence rate, adverse events, repetition of instructions during test performance, test duration, and number of oversteps were assessed. Adherence rate was excellent (100%), with no adverse events. No repetitive instructions were given during the test and test duration was short (mean time = 17.16s) with few oversteps (mean oversteps made = 1.94 oversteps). Test-retest reliability for participants without a walking device was excellent for the GMWT time score (ICC = .942; Minimal Detectable Change (MDC) = 2.96s). Test-retest reliability for participants with a four-wheeled walker was moderate (ICC = .837; MDC = 10.35s). Reliability for the overstep score was marginal (ICC = .630; MDC = 4.38 oversteps). Concluding, the GMWT is a feasible test for older adults with dementia. To monitor walking abilities in patients with dementia, the GMWT time score is a reliable and sensitive field test. The GMWT overstep score provides useful information about the execution of the test according to protocol.

Keywords Dementia, walking test, feasibility, reliability, minimal detectable change

Introduction

Compared with older adults who are healthy, their peers with dementia are about two to three times more likely to fall (de Carle AJ & Kohn R. 2001). The likelihood of falling in older adults who are cognitively impaired is related to a decline in executive function and a decline in dynamic

balance (e.g., balance during walking) (Liu-Ambrose T, Nagamatsu LS et al. 2013). Rehabilitation interventions to prevent falls in dementia patients should aim to enhance executive function and improve gait parameters that are involved in falls, including walking speed, gait width, and stride variability. In order to measure the effects of such interventions there is a need for feasible, reliable, and valid field tests, specifically tailored for patients with dementia. In order to provide such a test that fits this population, the Groningen Meander Walking Test (GMWT) was developed (Figure 1). The aim of the GMWT was to measure walking abilities by walking over a meandering curved line, with an emphasis on walking speed and stepping accuracy, while changing direction. The aim of the study was to investigate feasibility, test-retest reliability, and minimal detectable change (MDC) as a first step towards the clinimetric evaluation of the GMWT.

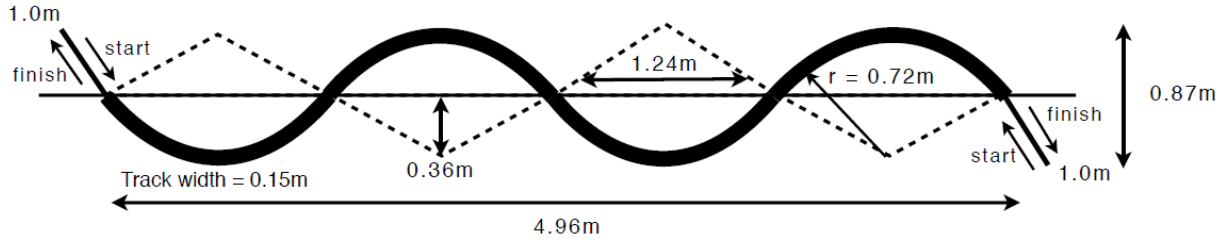

Figure 1. Dimensions of the Groningen Meander Walking Test (GMWT). r = radius to draw the curved GMWT path.

Methods

Participants

Forty-two participants (mean age ± SD = 87 ± 5 years; 21% male; mean Mini mental Status Examination Score ± SD = 17 ± 4) were recruited from four specialized nursing homes in and around Groningen in the Netherlands, meeting the following inclusion criteria: (1) age 70 or older, (2) Dutch native speakers, (3) diagnosis of dementia, (4) mini-mental status examination in the range of 9 to 24,and (5) able to walk independently with or without a walking device but without personal assistance.

GMWT

The dimensions of the GMWT are shown in Figure 1. The 6.00m track of the GMWT, which has four bends, was drawn on a smooth, dark blue mat. The width of the meandering track was 0.15m. To exclude the effects of start-up speed and slowdown speed, participants started the test 1.00m before the start of the track and stopped 1.00 m after the end of the track. The total test was performed in two parts: first forth and then back.

Instructions

Participants were instructed to walk as fast and accurately as possible. The instructions were: "*Please walk over the path as fast and accurately as possible. Try not to step outside the white lines. We will measure the time and count the number of times you step outside the lines*." No practice trial was included and a walking device was allowed.

Outcome measures

The first outcome measure was the time to perform the test. The forth and back walks were timed separately: the stopwatch was stopped once the participants finished the forth walk and was restarted once they started their walk back. The final score was the mean time (in seconds) of the forth and back walks. A faster time score indicated better performance. The second outcome measure, simultaneously measured with the time score, was the number of oversteps outside the

track. If the participant stepped completely outside the indicated track, this was noted as one overstep.

Statistics

Assessment of the test-retest reliability for the GMWT time and overstep scores was performed with a model 3 (2-way mixed) intraclass correlation coefficient (ICC) analysis. The ICC was calculated with a 95% confidence interval (95% CI), single measure, absolute agreement model.

Results

Forty-two participants performed both measurements of the GMWT according to protocol (adherence rate was 100%) and no adverse events occurred during test administration. Furthermore, only repetitive instructions were given to the participants before the second walk of the GMWT. Table 2 presents the GMWT time and overstep data.

Table 1. Groningen Meander Walking Test (GMWT) Time and overstep mean scores (standard deviation) for repeated measures T0 and T1, difference between T1 and T0 with their statistical value, intraclass correlation coefficient, standard error of measurement, and minimal detectable change at 95% confidence interval

	T0 Mean (SD)	T1 Mean (SD)	T1-T0 Diff.	ICC (95% CI)	SEM (95% CI)	MDC_{95}
GMWT Time (s)						
All (N=42)	16.93 (7.90)	17.39 (8.37)	0.46	.942 (.895-.968)	1.93 (1.64-2.54)	5.35
No Device (N=23)	13.19 (6.69)	13.33 (6.23)	0.14	.972 (.937-.988)	1.07 (0.84-1.54)	2.96
4-wheeled walker (N=19)	21.46 (6.90)	22.29 (8.11)	0.83	.748 (.707-.949)	3.73 (2.02-3.97)	10.35
GMWT Overstep (no.)						
All (N = 42)	2.11 (2.63)	1.77 (2.60)	-0.34	.630 (.409-.782)	1.58 (1.31-2.03)	4.38
No Device (N = 23)	1.37 (1.79)	1.13 (1.66)	-0.24	.672 (.371-.846)	0.98 (0.77-1.41)	2.71
4-wheeled walker (N = 19)	3.00 (3.21)	2.55 (3.29)	-0.45	.578 (.179-.813)	2.09 (1.61-3.15)	5.78

GMWT, Groningen Meander Walking Test; Diff., Difference T1 – T0; ICC, Intraclass Correlation; CI, Confidence Interval; SEM, Standard Error Measurements; MDC_{95}, minimal detectable change at 95% Confidence Interval

Conclusion

The GMWT is a feasible test to use in clinical practice and research. With the GMWT time score, a reliable and more sensitive field test for dynamic walking abilities in older adults with dementia is available. The GMWT overstep score can be used to give information about the execution of the test according to protocol and should be emphasized during the instructions. Future studies need to investigate the validity of the GMWT in older adults with dementia.

Acknowledgements

The authors thank all participants and health care institutions ZINN and Zorggroep Groningen for their cooperation.

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Comparison of balance outcomes between aquatic and land exercise in older adults with Osteoarthritis

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Abstract Balance improvement has been well documented in healthy older adults after participating in aquatic or land-based exercise programs. Aquatic exercise is frequently recommended for people with arthritis. While various effects of aquatic exercise have been studied, limited research has investigated its effects on balance among people with osteoarthritis (OA). The purpose of the study was to compare balance outcomes between aquatic and land-based exercise programs in older adults with knee OA. A total of 14 participants (Mean age 75.65 ± 8.2, 13 females, and 1 male) with knee OA were assigned to the Arthritis Foundation Aquatic Program (AFAP) or the Arthritis Foundation Land Program (AFLP). Participants completed 45-minutes of the assigned exercise program, 3 times a week for 12 weeks. Outcome measures were assessed by using a computerized posturographic balance test equipment (Neurocom Balance Master, NeuroCom International, Clackamas, OR, 2010), a psychometric balance measure, the activities-specific balance confidence (ABC) scale, a dynamic balance measure, the Timed Up and Go Test (TUG), a pain assessment measure, the visual analog pain scale (VAS), and a functional balance measure, the functional reach test (FRT). All tests were performed pre and post-intervention. Within group analyses using paired t-tests showed that the AFLP had no statistically significant changes between pre and post in any of the outcome measures. The water group showed significant changes between pre and post in the TUG and Limits of Stability (LOS- NeuroCom Test). MANOVA showed no group-interaction in any of the balance measures. As a total group, significant differences were found between pre and post in the FRT, TUG, and LOS. The findings indicate that aquatic or land exercise programs can help older adults with knee OA. Exercising in either program will show benefits in reaction time and in functional and dynamic balance.

Keywords Osteoarthritis, balance, exercise

Introduction

An estimate 30% of the population older than 65 years falls at least once a year, with an even greater fall risk seen in individuals with osteoarthritis (OA) in the lower extremities (Arnold CM, 2007). Aquatic exercise has been shown to decrease falls risk and improve balance in the elderly and in other populations (Arnold CM , 2010; Hale LA, 2012; Suomi R, 2000); exercising in land-based programs have seen similar results (Williams SB, 2010; Boeer J, 2010; Messier SP, 2000). Because previous studies show conflicting results based on which program improves balance performance to a greater extent, it is essential for further research of the effects on balance. The purpose of the study was to compare balance outcomes between aquatic and land-based exercise programs in older adults with knee OA.

Methods

Participants

14 individuals over the age of 55 years, with a medical diagnosis of knee OA and the ability to stand independently participated in the exercise intervention and completed pre and post-data collection procedures.

Intervention

The aquatic and land group participated in AFAP and AFLP respectively for twelve weeks (45-minute sessions, three days/week). The AFAP took part in a therapeutic pool (water temperature 92 degrees Fahrenheit, water depth 3.0-4.5 feet) while the AFLP took part in a gym.

Variables

The following variables were measured:

- Timed-Up and Go-Test (TUG): basic functional mobility
- Functional Reach Test (FRT): falls risk
- Activities –specific Balance Confidence (ABC) scale: balance confidence
- Visual Analog Pain Scale (VAS): pain level
- Neurocom Balance Manager tests (Smart Balance Master, Neurocom International, Clackamas, OR, 2010): Sensory Organization Test (SOT), Motor Control Test (MCT), Adaptation Test (AT), Limits of Stability Test (LOS)

Statistics

Within group analyses were examined using paired t-tests. Between group differences were examined using a general linear model (MANOVA). All statistical analyses were calculated using the SPSS (SPSS software, version 17, SPSS Inc. Chicago, IL). All statistical tests were performed at the $p < 0.05$ significance level.

Table 1. Participant demographics

Variable	AFAP n=6 (SD)	AFLP n=8 (SD)
Age (years)	76.3 (9.5)	75 (6.9)
Gender	6 females	7 females, 1 male
Body mass index (kg/m^2) *	34.15 (73.09)	23.63 (2.18)

Results

At post-intervention, the AFAP showed significant improvements in the TUG (14.06 (5.13) versus 10.85 (4.11), p= .012) and LOS (.93 (.30) versus .69 (.30), p= .048). In the AFLP, there were no significant improvements in any of the outcome measures. MANOVA results showed no significant group interaction (p=. 598). As a total group, there was a statistically significant

difference between pre and post in the FRT (F= 6.547, p= .025), TUG (F= 11.79, p= .005), and LOS (F= 11.92, p= .005). (Table 2-3).

Conclusion and discussion

The results from this study demonstrated that twelve weeks of aquatic and/or land exercise, based off of Arthritis Foundation guidelines was beneficial in improving dynamic balance (TUG), functional balance (FRT), and reaction time (LOS) in older adults with knee OA. More than 50% of the land participants had a perception of balance improvement and 50% of the aquatic participants had lower levels of pain and greater flexibility. The present study has been the only one to date to show improvements in the TUG and LOS in an aquatic setting. Participants in our study were at a lower risk for falls after participating in either the aquatic or land programs as indicated by faster walking times in the TUG. Improvements in the functional balance (as measured by the FRT) indicate greater ability to reach further without falling/losing balance and can make older people more independent in performing ADL's. A possible explanation for why the AFLP or AFAP did not show any significance in the NeuroCom measures (SOT, MCT, and AT) was because the testing tool consisted of force plate movements (involuntary/voluntary) while the training tool in which intervention was held for 12 weeks had participants in a stable ground with no sudden movements of the floor. Aquatic and land exercise based on Arthritis Foundation guidelines are effective in improving the dynamic balance, functional balance, and reaction time in older adults with knee osteoarthritis.

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Effects of body weight-supported treadmill training on heart rate variability in spinal cord injury

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Abstract The purpose of this study was to investigate the effects of 6 weeks of BWSTT on autonomic regulation, measured by heart rate variability (HRV) in people with incomplete SCI in chronic stage. Autonomic nervous system function can be indexed non- invasively by HRV, a measure of beat to beat temporal changes in the heart rate (HR). High frequency (HF) HRV represents a rhythmic fluctuation of the HR in the respiratory frequency band and has been demonstrated to be an indicator of parasympathetic control and vagal tone. Another indicator of parasympathetic activity that we analyzed are the standard deviation of the 5- minute average R-R intervals (SDANN) and the root mean square of differences of successive R-R intervals (RMSSD). The Interbeat intervals were measured for 5 min via the Polar RS800CX (Polar Electro Oy, Kempele, Finland) HR monitoring system at 1000 Hz, which wirelessly receives HR data from a chest strap worn by participants. Four individuals with SCI with more than twelve months of evolution participated. Three measures of HRV were performed during the training protocol. The first measure was made before entering the training protocol, the second measure was made at the end of the third week of training, and the third measure was performed once the treadmill gait training with body weight support protocol had been completed. The subject with SCI showed significantly higher HRV, measured with the mean of the root mean square of differences of successive RR intervals (RMSSD), and the mean of the HRV high frecuency power, at the end of the training protocol. From a physiological perspective, our results demonstrate that individuals with incomplete SCI retain the ability to make positive changes to their autonomic regulation of the cardiovascular system with BWSTT. Our results reflect that this exercise training modality may confer cardiovascular benefits to individuals with incomplete SCI.

Keywords Spinal cord injury, body weight support, heat rate variability.

Introduction

Individuals with spinal cord injury are prone to cardiovascular dysfunction and an increased risk of cardiovascular disease. Body weight-supported treadmill training (BWSTT) may enhance ambulation in individuals with incomplete spinal cord injury; however, its effects on cardiovascular regulation have not been investigated (Ditor 2005). Locomotion training in patients with spinal cord injury involves great physical and cardiovascular effort, which has rarely been standardized and described for the different stages of rehabilitation. Today there are few publications that relate locomotion training using body weight support treadmill with standardized parameters reflecting cardiovascular fitness. For this reason, in this study we propose measure changes in physical condition through the measurement of heart rate variability as an objective marker of autonomic balance in subjects with incomplete spinal cord injury in a chronic stage (Gavin 2005).

Methods

Four individuals with SCI with more than twelve months of evolution participated in this study. All were classified with an incomplete injury class D according to the American Spinal Injury Association. The subjects did not have any diseases related with the autonomic nervous system or cardiovascular system. The subjects diagnosed with SCI participating in the study were volunteers, and none of them were hospitalized.

Each received training on a treadmill with the use of body weight support for six weeks. Three measures of HRV were performed during the training protocol. The first measure was made before entering the training protocol, the second measure was made at the end of the third week of training, and the third measure was performed once the gait training on body weight support treadmill protocol was completed (at the end of the sixth week).

Heart rate variability measured during 5 min via the Polar RS800CX (Polar Electro Oy, Kempele, Finland) heart rate monitoring system at 1000 Hz, which wirelessly receives HR data from a chest strap worn by the participants.

Variables

The following variables were measured HF, High frequency HRV represents a rhythmic fluctuation of the HR in the respiratory frequency band and has been demonstrated to be an indicator of parasympathetic control and of vagal tone. SDANN, the standard deviation of the 5-minute average R-R intervals RMSSD, root mean square of differences of successive R-R intervals NN50, the number of successive interbeat intervals which differ by more than 50 ms.

Results

Preliminary outcomes in subjects with SCI showed changes in HRV, measured with the root mean square of differences of successive RR intervals (RMSSD), the mean of the HRV high frecuency power, and NN50 at the end of the training protocol.

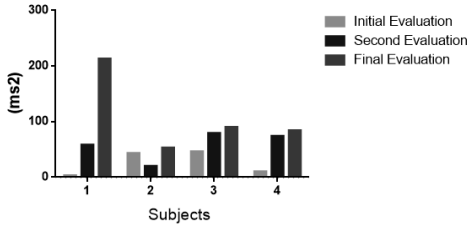

Figure 1. RMSSD during training program

In all four cases, an increase of RMSSD derived from the HRV was observed, comparing the initial evaluation versus the final evaluation.

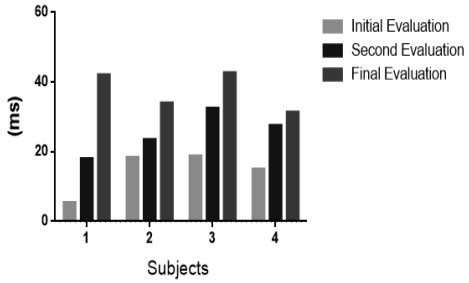

Figure 2. HRV HF power during training program.

In all four cases, an increase in HF power was observed, comparing the initial evaluation versus the final evaluation**.**

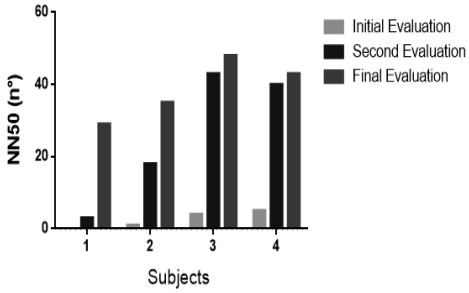

Figure 3. NN50 measured during training program.

In all four cases, an increase in NN50 derived from the HRV was observed, comparing the initial evaluation versus the final evaluation.

Conclusion

Changes in individuals with incomplete SCI observed in this study are important because they demonstrate that only six weeks of training with BWS produce positive changes to the autonomic regulation of the cardiovascular system.

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Effect of seat height on hand rim wheelchair performance

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Abstract *Purpose:* The use of a manual wheelchair in activities of daily life (ADL) leads to a high strain, which in turn leads to a high risk of overuse injuries of the upper extremities. To decrease the high daily physical strain the wheelchair should fit optimally to the active user. The aim of this study was to determine the relation between seat height, expressed in elbow angle, to physiological variables and propulsion technique during submaximal wheeling on a motor driven treadmill. *Methods:* Four absolute wheelchair seat heights were tested in twelve inexperienced able-bodied males. Seat heights 1 till 4 were performed randomly in 14 x 4 min of submaximal steady state wheelchair propulsion on a motor-driven treadmill. The following outcomes were measured; VO_2 (L/min), RER, mechanical efficiency (ME), cadence (pushes/min), contact angle (deg), peak force(N), FEF (%), cycle time (sec), push time (Sec), slope (Nm/s), power output (P_o) and the negative dips (N) before and after the push. Multilevel modeling (MLwin) was used to analyze the effect of seat height (elbow angle)on these variables while correcting for a fluctuation in Po. *Results:* ME, peak force and the slope were significantly influenced by seat height. Based on the multilevel model, during propulsion at 15 watt power output, a 10 degree increased elbow angle (i.e. seta height) will result in an 0.10% increased ME. Simultaneously, a similar 10 degree increase will result in a decreased peak force of 7.75 N, while the slope of the torque decreased with 11.15 (Nm/s). *Conclusion*: Based on the results of the current study and on international literature we can conclude that individual fitting of seat height is beneficial in terms of ME and propulsion technique variables. An improvement in ME and peak force as a result of a better individual fitting to the wheelchair potentially decreases the physical strain of daily wheelchair use.

Aerobic exercise capacity after burn injury in children and adolescentsin the Netherlands

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Abstract *Purpose:* Burn injuries have a major impact on the patient's physical and psychological functioning. The consequences can, especially for pediatric burns, persist long after the injury. Loss of physical fitness after burns seems logical, considering inflammatory and stress responses and a long period of bed rest. However, knowledge on the possibly affected levels of physical fitness is limited and pertains only to children with exceptionally severe burns. To extend our knowledge on the Dutch population, this study aimed to determine levels of aerobic exercise capacity in children and adolescents with a wider range of burn characteristics. *Methods:* Children and adolescents aged 6 to 18 years were invited to participate in the current cross-sectional descriptive study if they had been admitted to one of the dedicated Dutch burn centers between 0.5 and 5 years ago with a burn injury involving at least 10% of the total body surface area [% TBSA]. As part of a larger study, aerobic exercise capacity was assessed with a cardiopulmonary exercise test using a cycle ergometer and gas analysis in a mobile exercise lab, parked near the children's homes. Primary outcome parameter was aerobic exercise capacity (VO_{2peak} [$ml*min^{-1}$]) and scores were compared with age and sex matched reference values. *Results:* The study population consisted of 22 children and adolescents (12 boys; 6-18 years; 10-41% TBSA). In the majority of children, results on aerobic exercise capacity showed no significant deviation from reference values. The mean Z-score was -.23 ± .92 and the mean score relative to predicted values was 97.3% ± 12.8. One subject however, did show pathologically low outcomes on VO_{2peak} [$ml*min^{-1}$]. No trends were found indicating an effect of extent of burn or time post burn on aerobic capacity in this group. *Conclusions:* Aerobic exercise capacity is adequate at 1-5 years after burn injuries of 10-41% TBSA in the majority of children and adolescents in the Netherlands.

Keywords burns, children, exercise tolerance

Introduction

Burn injuries can have a major impact on the patient's physical and psychological functioning. Children form a risk group for burn injury and the consequences can persist long after the injury. Loss of physical fitness after burns seems logical, considering inflammatory and stress responses and a long period of bed rest. However, knowledge on the possibly affected levels of physical fitness is limited and pertains only to children with exceptionally severe burns (>40% of the total body surface area [TBSA]). Aerobic exercise capacity was shown to be affected up to 9 months post burn in this group (for review, Disseldorp et al., 2011). As burns of >40% TBSA are rare in the Netherlands, this raised the question whether exercise capacity is also limited in children with

less extensive burns and/or at a longer period post burn. To extend our knowledge, this study aimed to determine levels of aerobic exercise capacity in children and adolescents in the Netherlands with a wider range of burn characteristics.

Methods

Children and adolescents aged 6 up to and including 18 years with burn injuries of at least 10% TBSA were invited to participate if they had been admitted to the burn center between 0.5 and 5 years ago (at time of inclusion).

Anthropometry and exercise capacity of pediatric burn patients were assessed once as part of a larger study, for detailed protocols see Disseldorp et al., 2012. The assessments took place in a mobile exercise lab parked near the participant's home. This truck was specially equipped for (among others) cardiopulmonary exercise testing, for which an electronically breaked cycle ergometer and metabolic cart for breath analysis were used and heart rate monitoring was applied.

Main outcome variable was peak oxygen uptake (VO_{2peak}), given as both absolute value and relative for body mass. VO_{2peak} and VO_{2peak}/kg were calculated as average of the values taken from the last 30 seconds of the incremental cardiopulmonary exercise test. To enable comparison to a Dutch non-burned (healthy) population, recently published age- and sex-matched norm values (Bongers et al., 2012) were used.

Results

Inclusion rate of the larger study was about 54%, which resulted in 25 participants (Disseldorp et al., 2012). For this current part outcomes of the incremental exercise tests of 22 subjects were analysed, of which 12 boys; see Table 1 for more characteristics.

Table 1. Subject characteristics

	Range
Age [years]	6-18
Age at burn incident [years]	2-17
% TBSA	10-41
Time post burn [years]	1-5
Number of surgeries	0-3

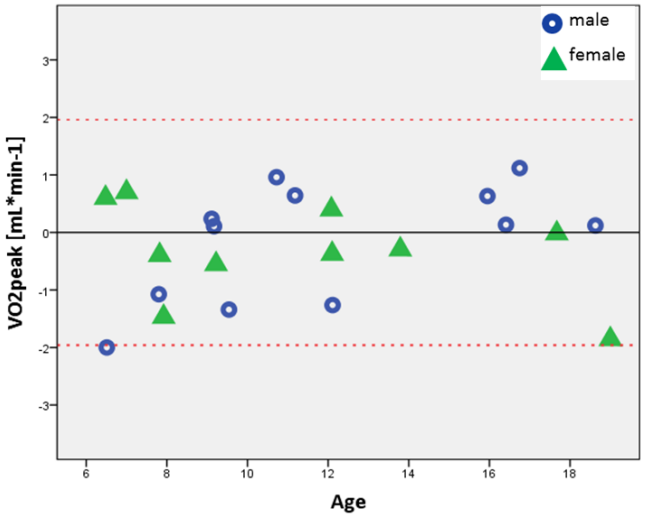

Figure 1. Peak oxygen uptake for all participants, expressed as Z-scores calculated by using matched norm values (Bongers et al., 2012), plotted against age

Mean Z-score for main outcome variable VO_{2peak} was -.23 (range: -2.00 – 1.12). The one subject that showed significantly low outcomes was a boy aged 6.5 years; 10% TBSA, 4.6 years post burn (Figure 1).
For VO_{2peak}/kg one other subjects scored significantly low: a 18.9 years aged girl with 41% TBSA burns, 2 years post burn. No trends were found indicating an effect of extent of burn or time post burn on aerobic capacity in this group.

Conclusion and discussion

The use of a mobile exercise lab enhanced the feasibility of the study and the protocol succeeded to include subjects with a large range of burn characteristics. Nevertheless, it is possible that children who are interested in sports and a healthy lifestyle, were more inclined to participate than children who are not. A longitudinal study is necessary to indicate risk factors for deconditioning after burns.

Aerobic exercise capacity is adequate after burns of 10 – 41% TBSA in the majority of Dutch pediatric burn patients at 0.5 – 5 years post burn.

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Association of shoulder problems in persons with spinal cord injury at discharge from inpatient rehabilitation with activities and participation at 5 years later

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Abstract *Objective:* To examine the association of musculoskeletal shoulder pain and limitations in shoulder range of motion (ROM) at discharge from first rehabilitation with activities and participation five years later in persons with spinal cord injury (SCI). *Design:* Prospective cohort study. *Participants:* 138 subjects with a newly acquired SCI. *Setting:* eight SCI specialized rehabilitation centers. *Interventions:* Not applicable. *Main outcome measures:* Peak exercise performance (POpeak), Wheelchair skills test (WST), Functional Independence Measure (FIM)-Motor Score, ability to transfer, Physical activity Scale for subjects with a Disability (PASIPD), Mobility Range and Social Behavior scales of the Sickness Impact Profile 68 (SIPSOC) and employment status. *Results:* Mean age of the subjects at discharge was 39 years, 72% were male, 32 % suffered a tetraplegia, and in 65% the SCI was motor complete. At discharge 39% reported shoulder pain and 32% had a limited shoulder ROM. In the analyses of variance Shoulder ROM limitation, but not shoulder pain was associated with all but one outcomes at 5 years. In the regression analyses ROM limitations of the shoulder were negatively associated with ability to transfer (Beta -0.26, p=0.001), FIM-Motor Scores (Beta -13.45, p<0.001), and return to work (Beta -3.3, p= 0.001) 5 years after discharge. No significant associations were found with POpeak, performance of time of WST, SIPSOC, and the PASIPD. *Conclusions:* The presence of limitations in shoulder ROM, but not shoulder pain, at discharge is associated with limitations in activities and employment status 5 years later.

Key Words: shoulder, pain, spinal cord injury, longitudinal, cohort

Introduction

Persons with a spinal cord injury (SCI) are more at risk for developing overuse related shoulder problems than those without SCI.[1] Estimations of limitations in shoulder ROM vary between 29 %

and 70%[2, 3], while shoulder pain is reported in up to 67% in persons with SCI.[4, 5] It is necessary to know the association between shoulder impairments during inpatient rehabilitation and long term activities and participation in order to timely intervene. The objective of the current study was: To use the bio-psychosocial framework of International Classification of Functioning, Disability and Health (ICF)[6] to examine the associations of musculoskeletal shoulder pain and limitations in shoulder ROM at discharge from first rehabilitation with activity limitations and participation restrictions 5 years after discharge**.**

Methods

Study design

A multicenter prospective cohort study was conducted with measurements at discharge from inpatient rehabilitation and five years after inpatient rehabilitation.

Subjects

Subjects were persons with a recently acquired SCI who were included in the longitudinal Dutch cohort study "Physical strain, work capacity and mechanisms of restoration of mobility in the rehabilitation of individuals with spinal cord injury".[7] Inclusion criteria were; (1) age between 18 and 65 years; (2) AIS grade A, B, C, or D; (3) expected permanent wheelchair dependency for long distances. For the current study subjects (n=138) who completed the measures of shoulder ROM and pain assessment at discharge and completed at least the questionnaire data 5 years after discharge were included.

Study outcomes and statistical analysis

First, analysis of variance (ANOVA) was performed to describe the association of the independent variables (shoulder pain and shoulder ROM) with the outcome variables. In the analyses we distinguished 4 subgroups; a) no ROM limitations/no pain, b) ROM limitations/no pain, c) no ROM limitations/pain and d) ROM limitations/pain ($p<0.05$).Secondly, using backward regression analyses, shoulder pain and shoulder ROM limitations at discharge were entered as independent variables to predict activities and participation five years later. Shoulder ROM and shoulder pain were included in all analyses, whereas possible confounders that were taken into account, were age, gender, SCI characteristics (level and completeness), time since injury and being overweight.

Results

Mean age of the subjects at discharge was 39 years, 72% were male, 32 % suffered a tetraplegia, and in 65% the SCI was motor complete. At discharge 39% reported shoulder pain and 32% had a limited shoulder ROM. In the analyses of variance Shoulder ROM limitation, but not shoulder pain was associated with all but one outcomes at 5 years. In the regression analyses ROM limitations of the shoulder were negatively associated with ability to transfer (Beta -0.26, $p=0.001$), FIM-Motor Scores (Beta -13.45, $p<0.001$), and return to work (Beta -3.3, $p= 0.001$) 5 years after discharge. No significant associations were found with POpeak, performance of time of WST, SIPSOC, and the PASIPD.

Conclusions

The presence of limitations in shoulder ROM, but not shoulder pain, at discharge is associated with limitations in activities and employment status 5 years later.

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Energy expenditure during sport activities in patients during rehabilitation

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Abstract The aim of the study was to examine 1) the energy expenditure during sport activities of patients during rehabilitation and 2) whether the Dutch Standard for Healthy Exercise (DSHE, duration of 30 minutes and an intensity of 4-6.5 times the metabolic equivalent (MET)) is achievable for patients during rehabilitation. The patients (N=54) were divided into 4 groups based on their disability: spinal cord injury (SCI) (N=15), amputation (N=13), stroke (N=17) and a group with other disabilities (N=9). Energy expenditure was measured with a mobile metabolic cart during different sport activities such as fitness, (hand)biking and table tennis. In 23 participants the energy expenditure during rest was measured to be able to calculate the intensity in MET. The subjective load intensity of the physical activities was determined with the BORG-Rating of Perceived Exertion (RPE) scale. Kruskal Wallis and one-way ANOVA were used for analyzing the difference in energy expenditure between the groups for the measurements during rest and during sport activities, respectively. The Spearman rank-order correlation was used to determine the correlation between the BORG-RPE score with the MET score. The energy expenditure during sport activities in SCI was significantly lower (0.85 kcal/min) compared to the amputation group (1.43 kcal/min) and the group with other disabilities (1.73 kcal/min). The MET score showed a significant moderate correlation with the BORG-RPE score (R2=0.276). 24% Of the participants achieved the DSHE regarding intensity and 11% achieved the standard regarding intensity and duration. The energy expenditure during sport activities is lowest for people with SCI during rehabilitation. Only 11% of the people with disability achieved the DSHE during rehabilitation, which is much lower at comparable physical activity levels compared to healthy people.

Keywords Energy expenditure, rehabilitation, sport, MET, BORG-RPE, spinal cord injury, amputation, stroke.

Introduction

Physically disabled people have a greater risk to become overweight or obese compared to healthy people. This is mainly caused by a sedentary lifestyle, most of the physically disabled people are dependent on wheelchairs. For people with spinal cord injury (SCI) it is known that they have a decreased energy expenditure during rest, as well as during exercise. This is caused by the decreased amount of fat-free mass as a result of atrophy of the paralyzed muscles (Buchholz et al, 2004).

In order to keep the community physically active the Dutch Standard for Healthy Exercise (DSHE), was created. The DSHE guidelines prescribe exercise of a duration of 30 minutes and an intensity of 4-6.5 times the metabolic equivalent (MET). The aim of the current study was to

examine 1) the energy expenditure during sport activities of patients during rehabilitation and 2) whether the DSHE is achievable for patients during rehabilitation.

Methods

Participants

54 Patients have participated in this study. They were divided into 4 groups based on their disability: spinal cord injury (SCI) (N=15), amputation (N=13), stroke (N=17) and other disabilities (N=9). All of the participants were patients in the rehabilitation center Reade, Amsterdam.

The following variables were measured for the study:

- The pulmonary gas exchange was measured with a mobile metabolic cart, the COSMED K4b2, during the different sport activities given in the rehabilitation center.
- The subjective load intensity of the physical activities was determined with the BORG-RPE scale.
- Pulmonary gas exchange during rest was measured with a mobile metabolic cart, the COSMED K4b2, for the calculation of the metabolic equivalent (MET).
- A questionnaire was used to determine the personal variables like, age, gender, body mass index (BMI) and disability.

The energy expenditure was calculated with the following formula (Garby and Astrup, 1987):

*Energy expenditure (Joule/min) = VO2 (L/ min) * (4940* RER + 16040)*

with Respiratory Exchange Ratio (RER) = VO2 / VCO2

Energy expenditure was converted to kcal/min with the following formula:

Energy expenditure (kcal/min) = energy expenditure (joule/min)/ 0,0041876

The MET was calculated with the following formula:

MET = oxygen consumption during sport activity (mL.kg-1.min-1) / oxygen consumption during rest (mL.kg-1.min-1)

Statistics

Kruskal Wallis, a non-parametric test, ($p \leq 0.05$) and one-way ANOVA ($p \leq 0.05$) were used to analyze the significant difference in energy expenditure between the groups for the measurements during rest and during sport activities. The Spearman rank-order correlation ($p \leq 0.05$) was used to determine the correlation between the BORG-RPE and the MET score.

Results

Table 1 represents the mean and standard deviations of the patient characteristics.

Table 1. Patient characteristics (N=54)

Participants	Mean (SD)
Age [years]	48,9 (±11,9)
Length [centimeter]	176,2 (±10,9)
Weight [kilogram]	79,2 (±16,2)
BMI	26,2 (±5,2)[a]
Duration of rehabilitation [months]	5,3 (±4,9)[b,c,d]
Gender, man [%]	77,8

Disability [%]	
SCI	27,8
Stroke	31,5
Amputation	24,1
Other disabilities	16,7

[a] Significant difference between the amputation and the SCI group (p=0,004).
[b] Significant difference between the SCI and the stroke group (p=0,046).
[c] Significant difference between the amputation and the other disabilities group (p=0,008).
[d] Significant difference between the stroke and the other disabilities group (p=0,009).

Energy consumption

Table 2 represents the mean and standard deviations of the energy expenditure during the sport activities and the MET values sorted by disability.

Table 2. Energy expenditure during sport activities, MET and BORG-RPE score sorted by disability (mean, SD).

Disability:	Number of measured people:	Energy expenditure activity (kcal/min)	MET	BORG-RPE
SCI	19	2,37 (±0,80)[a,b]	2.98 (±1,25)	11,67 (±3,01)
Stroke	17	3,60 (±0,80)[a]	2,73 (±1,07)	13,00 (±2,71)
Amputation	13	3,11 (±1,06)	2,14 (±0,51)	10,86 (±2,85)
Other disabilities	9	3,10 (±0,84)[b]	1,83 (±0,46)	10,50 (±3,12)

[a] Significant difference between the stroke group and the SCI (p=0,006).
[b] Significant difference between the other disabilities group and the SCI group (p=0,034).

Movement standard

13 Of the 58 measurements met the DSHE prescription in the intensity (24%), 6 of these measurements also met the DSHE prescription in the duration of 30 minutes (11%). There is a significance moderate correlation between the MET and the BORG-RPE score, $r(56)=0,276$, $p< 0,05$.

Conclusion

The energy consumption during sport activities in patients during rehabilitation is lower compared to healthy people, this might be caused by the sedentary way in which the patients exercise. The MET is also lower in the patients compared to healthy people. Most (76%) of the physical activities carried out by the patients did not meet the DSHE prescription.

Acknowledgements

The authors of this study would like to thank Rehabilitation Research Center Reade, Amsterdam for their cooperation, for providing research areas and equipment, and especially thanks to the sports therapists and physiotherapists for their assistance in finding research participants.

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Mountain time trial in handcycling: pilot study on exercise intensity and predictors of race time

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Abstract The purpose of this study was to analyze the exercise intensity during a mountain time trial in handcycling and to determine predictors of the race time. 47 Participants with a lower-limb disability participated in a 20.2 km handcycling mountain time trial. The heart rate (HR) was monitored in 19 of the 47 participants during the race to determine the exercise intensity. Exercise intensity was expressed relative to the heart rate reserve (%HRR). Two weeks prior to the race all participants also completed laboratory tests to ascertain anthropometric measures as well as peak values for power output (POpeak), oxygen uptake (VO2peak) and heart rate (HRpeak). The mean race time was 3 hours and 59 minutes (SD: 1 hour and 30 minutes). The mean exercise intensity during the race was 71±8%HRR. The exercise was mainly (75% of the race time) at a vigorous intensity (60-89%HRR), with 32% of the total time in the 80-89%HRR zone. The strongest predictors for the race time were mean %HRR during the race (R^2=64%), waist circumference (R^2=46%), VO2peak (R^2=44%), and POpeak (R^2=42%). It can be concluded that a 20 km mountain time trial in a handcycle is intensive. Recreational handcyclists showed a lower mean exercise intensity due to regular stops. Faster race times were achieved in those individuals with a lower waist circumference, greater fitness levels and ability to perform at higher average exercise intensities during the race.

Keywords Wheelchair sports, performance, physiological capacity, heart rate

Introduction

Handcycling is becoming increasingly popular in individuals with a lower-limb disability for both mobility and sports. The popularity can be explained by its ease of use together with a relative low physiological (Dallmeijer, Zentgraaff et al., 2004) and mechanical strain (Arnet, van Drongelen et al., 2012). To achieve the best handcycle performance in daily life or sports a good training program is important. But what is the best training regime for handcyclists who want to compete in a mountain time trial? The distribution of exercise intensity zones for mountainous handcycling races is more than likely to be different to that seen in other handcycling races. Furthermore, to optimize the performance, analyzing predictors (e.g peak power output, classification, body mass and/or mass of the handcycle) of the race time might also be helpful.

Therefore, the purpose of this pilot study was: 1) To analyze the exercise intensity of mountain handcycling race; and 2) To determine predictors of the handcycling race performance.

Methods

Participants

47 Handcyclist participated in the race and, due to the available heart rate monitors, the heart rate was monitored during the race in a subgroup (N=19).

Design

The handcyclists participated in a mountain time trial among teams from eight Dutch rehabilitation centers. The 20.2 km race was held in June 2013 on the Kaunertaler Gletscherstrasse in Austria, starting at the toll gate (1287m) and ending at the Ochsenalm (2150m). In the two weeks prior to the race, participants attended the laboratory to determine physical capacity (peak oxygen uptake (VO2peak), peak power output (POpeak), and peak heart rate (HRpeak) during graded exercise test and personal and handcycle characteristics. The heart rate was recorded continuously during the race. The exercise intensities were determined and classified relative to the heart rate reserve (%HRR): very light (<30%HRR), light (30-39%HRR), moderate (40-59%HRR), vigorous (60-89%HRR), and near maximal to maximal (90-100%HRR).

Statistics

An univariate multi-level regression analysis was performed with race time (in minutes) as dependent variable. Independent variables were personal characteristics (age, gender, classification (H1/H2=0; H3/H4=1), body mass, body mass index, waist circumference), handcycle mass, hours per week involved in sports or handbike training, fitness level (POpeak, VO2peak), HR parameters during the race (%HRRmean, %time in different intensity zones). Level of significance was set at $p<0.05$.

Results

Exercise intensity

The average %HRR during the race was 71±8%, ranging between 60-83%. The participants exercised most of the time (75%) at a vigorous intensity, especially in the 80-89%HRR zone (32% of the total time) and 70-79%HRR zone (28% of the total time). Figure 1 shows the %HRR response of a recreational handcyclist during the mountain trial.

Predictors of race performance

The mean race time was 3 hours and 59 minutes (SD: 1 hour, 30 minutes). Waist circumference, handbike mass and fitness level (POpeak and VO2peak) explained each between 34-47% of the race time. Persons with a smaller waist circumference, lighter bike and better fitness level had a better race performance. The exercise intensity during the race (%HRRmean) explained 64% of the race time and the percentage time in different intensity zones explained 29-70% of the race time. The race time was better when the average exercise intensity was higher, the percentage time in the very light to vigorous intensity (in the 60-69%HRR) zone was lower or the percentage time in the 80-89%HRR zone was higher.

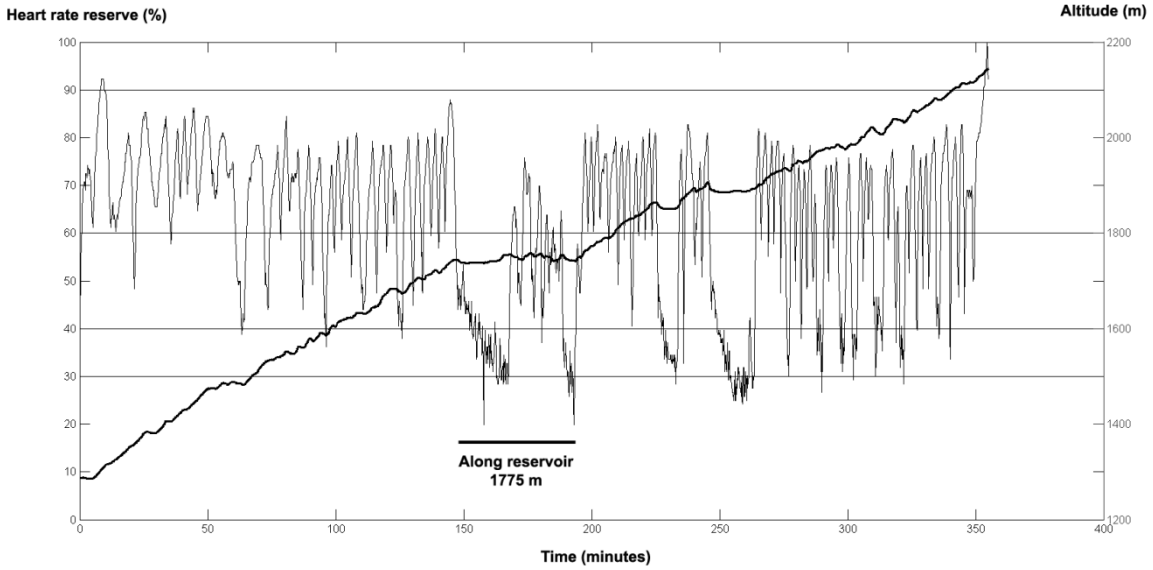

Figure 1. Altitude (bold solid line, right y-axis) and heart rate response (%HRR, left y-axis) of one of the recreational handcyclist. The horizontal lines indicate the %HRR zones. The bumpy altitude line indicates the multiple stops for this recreational handcyclist during the race. Average %HRR during the race of this participant is 62%.

Conclusion

A 20 km mountain time trial in a handcycle is intensive. Recreational handcyclists showed a lower mean exercise intensity due to regular stops. The results of the present study showed that to optimize the race performance it is important to be fit, with a small waist circumference and to have a light-weight handbike. Since a large majority of a mountain time trial is performed for long durations at a vigorous exercise intensity (70-89%HRR), it is advisable for training to incorporate this in the program.

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Stride frequency and length adjustments in post-stroke individuals; The influence on the margins of stability

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Abstract The aim of this study was to investigate whether post-stroke participants are able to walk at different combinations of stride frequency and stride length and how these adaptations affect backward and medio-lateral margins of stability. Ten stroke patients walked 6 trials of 2 minutes on a treadmill at different combinations of stride frequency and stride length. Treadmill speed was set at the corresponding speed, and subjects received visual feedback about the required and actual stride length. Stroke patients were well able to adjust stride length when this was required, but showed difficulties to adjust stride frequency. When a stride frequency higher than self selected stride frequency was imposed stroke patients needed to additionally increase stride length to be able to concur with the imposed treadmill speed. As a consequence, especially for the trials at a high stride frequency, the increase in the backward and medio-lateral margins of stability was limited. Therefore we concluded that training post-stroke individuals to increase stride frequency during walking might give them more opportunities to increase the margins of stability and consequently reduce fall risk.

Keywords Stroke; Gait; Rehabilitation; Accidental falls

Introduction

Multiple studies have shown that post-stroke individuals fall far more often than able-bodied people in the same age category. A method to quantify fall risk is by calculating the margins of stability (MoS) which describes the movement of the body CoM relative to the BoS (Hof et al., 2005). The MoS can be calculated in both medio-lateral (ML) and backward (BW) direction, where the BW MoS is usually calculated with respect to the posterior border of the base of support (BoS) of the leading foot at initial contact (figure 1). A negative ML MoS, implying that the extrapolated centre of mass (XCoM) is located lateral of the border of the BoS, will result in a deviation from the straight walking trajectory. In our definition a negative BW MoS implies that the XCoM is located posterior to the border of the BoS of the leading foot, which will result in an interruption of the forward progression (Hak et al., 2013).

Previously we established that post-stroke individuals were able to maintain or increase their ML MoS to the same degree as the able-bodied subjects (Hak et al., 2013). However the BW MoS was already lower during unperturbed walking compared to able-bodied controls and even further decreased during challenging walking conditions, while able-bodied people were able to maintain or increase their BW MoS during these conditions. This smaller BW MoS appeared to be caused by inadequate adjustments in stride frequency and stride length, resulting in a decrease in walking speed during the challenging conditions. However, these results do not elucidate whether post-stroke individuals are simply unable to use the same strategy as able-bodied controls, or prefer to use an alternative strategy for other reasons. The primary aim of the present study was to investigate whether post-stroke participants are able to walk at different combinations of stride frequency and stride length, both at a comfortable walking speed and at higher speeds. The second aim was to investigate how adjustments in stride frequency and length, and the concomitant change in walking speed influence the size of the BW and ML MoS and whether potential difficulties in adapting stride frequency and length limit the BW and ML MoS.

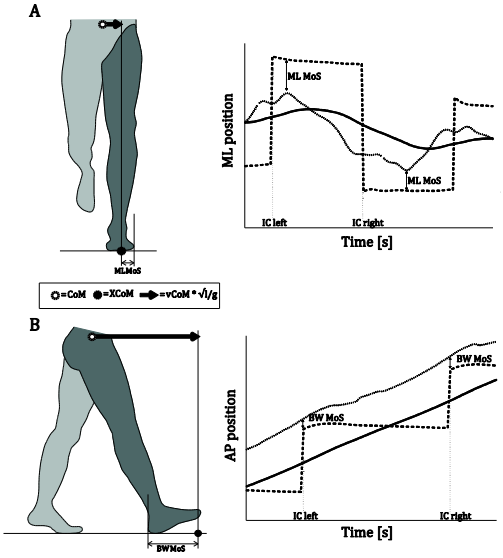

Figure 1: Schematic representation of the definition of the medio-lateral margin of stability (ML MoS) and backward margin of stability (BW MoS). A: The ML MoS is defined as the minimum distance in ML direction between the extrapolated centre of mass (XCoM; dotted line in the right panel) and the lateral border of the foot during foot-contact. The XCoM is calculated as the position of the centre of mass (CoM; dashed line in the right panel) plus its velocity (vCoM) times a factor $\sqrt{(l/g)}$, with l being the length of the pendulum (for which leg length is often used) and g the acceleration due to gravity B: The BW MoS is defined as the distance in anterio-posterior direction between the XCoM and the posterior border of the leading foot (solid line in the right panel) at initial contact. In the current study we have defined the BW MoS as positive when the XCoM falls anterior with respect the backward margin of the leading foot, like in figure B.

Methods

Subjects

Ten adult subjects (age 57.6 ± 15.4 years) who had suffered from a stroke participated in this study. All participants were still or again under treatment in the period in which the experiment took place.

Protocol

Subjects walked on the CAREN system (Motek Medical BV) at different walking speeds by either increasing stride length, stride frequency or both. Walking speed, stride length and hence also stride frequency were imposed as a percentage (90%, 100% or 111%) of the comfortable value. Subjects received visual feedback about the required and actual stride length and treadmill speed was fixed to the required speed for each trial .

Data collection and analysis

Kinematic data of markers attached at the lateral malleoli of the ankles, the pelvis (left and right anterior superior iliac spines, and left and right posterior superior iliac spines) were collected. Based on these data stride length, stride frequency and the MoS were calculated in ML and BW direction (figure 1).

Statistics

Generalized Estimating Equations (GEE) were used to evaluate the following regression equation: SL_{rel} = intercept + β_{SL}*imposed SL_{rel} + β_{SF}*imposed SF_{rel}, in which the realized relative stride length is expressed as a function of the imposed relative stride length and the imposed relative stride frequency. β_{SL} and β_{SF} are the regression coefficients. Because subjects walked at a fixed walking speed this regression equation could be used to establish whether subjects were able to adjust their stride length, but also their stride frequency following the instructions that were given. GEE were also used to investigate how performed SLrel and SFrel influenced the size of the ML and BW MoS and to predict values for the ML and BW MoS that could have been reached when subjects would have fully adapted their stride frequency and length to the imposed adjustments.

Results

Subjects adjusted stride length significantly when adjustments in stride length were imposed (βSL = 1.096; p<0.001). However, subjects also adjusted stride length when they were asked to adjust stride frequency (βSF = 0.263; p<0.001). This indicates that the adjustments in stride frequency were limited for these trials, and therefore adjustments in stride length were necessary to walk at the required treadmill speed. BW MoS increased both with an increase in stride length (βSL = 0.092; p<0.001) and with an increase in stride frequency (βSF = 0.437; p<0.001), while ML MoS only increased with an increase in stride frequency (βSF = 0.062; p<0.001). However, for the trials in which subjects were supposed to walk at a high stride frequency (111% of their comfortable frequency) the ML and BW could have been respectively 30% and 43% higher when subjects would have been fully able to increase their stride frequency up to the desired frequency.

Conclusion and discussion

In conclusion, the results of the present study indicate that post-stroke individuals have problems with increasing their stride frequency during walking. As a result of the limited capacity to increase stride frequency, also the capacity to increase the BW and ML MoS was limited, which places them at a higher risk of losing balance in sideward and backward directions. Although the exact cause underlying the observed limitation in stride frequency adjustments can not be derived from this study, training post-stroke individuals to increase stride frequency during walking might give them more opportunities to increase their MoS and consequently reduce fall risk.

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Effect of a 16-week low-intensity-wheelchair training on shoulder load in spinal cord-injured manual wheelchair-users

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Abstract High prevalence (31-71%) of shoulder pain in persons with spinal cord injury (SCI) limits performance of activities of daily life, which can lead to deconditioning and dependency. Insights in the effects of training on shoulder load are necessary to develop goal directed protocols to prevent shoulder pain. This study studied the effects of a low-intensity aerobic wheelchair exercise program on mechanical efficiency (ME), propulsion technique and shoulder load in persons with chronic SCI.A pre-post design was performed in 7 deconditioned persons with SCI, who followed a 16-week aerobic wheelchair training (30-40% Heart Rate Reserve, 2x30min/week). During a submaximal wheelchair exercise test on a motor-driven treadmill, respiratory gases were measured and kinetic and kinematic data collected. From these data, propulsion technique, ME and shoulder load were determined before, during and after the training. Mean and peak glenohumeral contact forces (GH forces) were calculated using an inverse dynamic model (Delft Shoulder and Elbow model) as measure for shoulder load. Both peak and mean GH forces showed a borderline significant decrease after 8 weeks of respectively 172.6 and 52.2N (P=0.06 & P=0.09). There was a significant reduction in propulsion frequency (from 50.3 to 38.3 push/min, P=0.01), the negative work at the start of the push (from -2.1 to -1.2W, P=0.02) and the energy expenditure (-19.8%, P=0.01). The reduction in energy expenditure did not lead to a change in ME. The results after 16 weeks could not statistically be analyzed: data of only three participants were available due to technical limitations and two participants who did not continue after 8 weeks. The indicated reduction in GH forces in combination with the decrease in propulsion frequency indicate a lower absolute strain during wheelchair propulsion after an 8-week low intensity training. This training may possibly reduce the risk of overuse complaints in the investigated population. More studies are needed to confirm these results in larger group of subjects with a control group.

ReSpAct: The implementation of a physical activity and sports stimulation program in Dutch rehabilitation

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Abstract PURPOSE: To perform a process evaluation of the implementation of the 'Rehabilitation, Sport and Exercise' (RSE) program in Dutch rehabilitation centers and hospitals. The RSE program aims to promote an active lifestyle in persons with a physical disability and/or chronic disease subsequent to their rehabilitation period. The study will provide more insight into factors that facilitate or hamper the implementation process. METHODS: The RSE program is being implemented in 18 centers and hospitals over a 3-year period (2012-2015). Managers, project leaders, physicians and counsellors of the participating centers will fill out theory-based questionnaires at the start (2013), after 1 year and at the end of the implementation process. Furthermore, patients participating in the program will fill out a questionnaire at the start, immediately after finishing the program and at a 33 and 52 weeks follow-up. The extent to which the RSE program is implemented in the participating organizations will be evaluated. Moreover, the study will result in an overview of facilitators and barriers of the implementation process. RESULTS: At baseline, 12 rehabilitation centers and 5 hospitals have commenced with the implementation of the RSE program. One hospital has not yet met the requirements for participation in the study. The number of patients who received a face-to-face consultation as part of the RSE program within each center/hospital varies from 0 (n=2 centers) to more than 20 patients per month (n=3 centers). All involved professionals (n=71) had a positive attitude towards the program. CONCLUSION: The unique implementation process of the nationwide RSE program will be extensively monitored. At baseline, a large variation in starting positions of the implementation was visible among the different centers/hospitals. Data collection of the process evaluation is ongoing and the results will be used to improve and optimize further dissemination of the program.

Keywords Physical activity, rehabilitation, implementation

Introduction

When a physical activity program has proven to be effective under controlled conditions, the next step is to introduce and evaluate the program in a real-world setting (Sallis et al. 2000). To successfully implement a new program into daily practice it is not only important that the program is effective, but also that the implementation strategy works. An evaluation of such an implementation process can be helpful and contribute to a better understanding of the outcomes of the program (Steckler and Linnan 2002). Moreover, such an evaluation allows identification of factors which lead to success or failure.

The evidence-based program 'Rehabilitation, Sport and Exercise' (RSE), which aims to promote an active lifestyle in persons with a disability and/or chronic disease subsequent to a rehabilitation period, is ready for nationwide dissemination in the Dutch rehabilitation setting (Van der Ploeg 2005). However, scientific research on factors that facilitate or hamper the implementation of an evidence-based program in a rehabilitation setting is scarce. Therefore, the aim of the present study is to perform a process evaluation of the implementation of the RSE program in eighteen Dutch rehabilitation centers and hospitals.

Methods

The RSE program

At the end of the rehabilitation treatment, patients can be referred to the RSE program to stimulate an active lifestyle by establishing a behavioral change. As part of the RSE program, patients will receive a face-to-face consultation on sport and exercise participation at home. After the end of the rehabilitation treatment, patients will receive four sessions of counselling by phone in order to further stimulate an active lifestyle at home. The RSE program is being implemented in eighteen rehabilitation centers and hospitals with a rehabilitation department over a 3-year period (2012-2015). All eighteen organizations are included in the process evaluation. The dissemination process is being coordinated by the Dutch Foundation 'Stichting Onbeperkt Sportief'.

Data collection and procedures

Managers, project leaders, physicians and counsellors in the participating centers and hospitals fill out theory-based questionnaires at the start (2013), after 1 year (2014) and at the end (2015) of the implementation process. The questionnaires consist of questions about the extent to which the RSE program is implemented and possible factors that hamper or facilitate this process. The content of the questionnaire was based on the research of Fleuren et al. (2004) and Grol et al. (2003). To collect both quantitative and qualitative data, a mix of closed-ended questions and open-ended questions is used.

Patients participating in the RSE program are asked to fill out a questionnaire at the start, immediately after the program and at a 33 and 52 week follow-up. This questionnaire consists of questions about their physical activity behavior, quality of life and their opinion/ satisfaction about the RSE program.

During the implementation period (2013 – 2015), the extent to which the RSE program has been implemented in the different organizations will be extensively monitored. Furthermore, this study will result in an overview of facilitators and barriers to the implementation of the RSE program. This paper presents a description of the starting positions of the implementation of the RSE program in the participating rehabilitation centers and hospitals.

Results

At baseline, twelve rehabilitation centers and five hospitals have commenced with the implementation of the RSE program. One hospital has not yet met the requirements for participation in the study. The baseline questionnaire was filled out by 11 managers, 9 project leaders, 13 physicians and 28 counsellors. Furthermore, 10 professionals who fulfilled a combination job (manager + project leader [n=6] and project leader + counsellor [n=4]) filled out a combination questionnaire. A total of 71 out of 75 professionals filled out the questionnaire at baseline (response rate = 94.7%). Data collection on the level of the patient is ongoing.

Starting positions of participating rehabilitation centers and hospitals

As shown in figure 1. the average number of patients who received a face-to-face consultation on sport and exercise participation at home varies from 0 (n=2 organizations) to more than 20 patients per month (n=3 organizations). Similarly, the average number of patients who received more than one counselling session after rehabilitation each month ranges from 0 (n=4 organizations) to 15 - 20 patients per month (n=2 organizations). All professionals (n=71) had a positive attitude towards the RSE program.

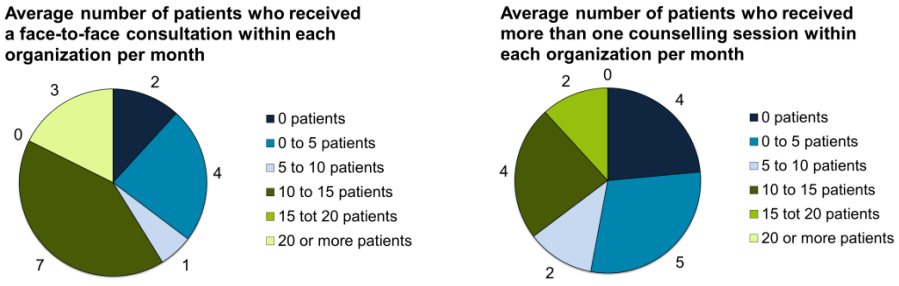

Figure 1. Starting positions of the implementation of the RSE program in the participating rehabilitation centers and hospitals (May 2013). The average number of patients who received a face-to-face consultation (left) and who received more than one counselling session per month (right) are presented for each organization.

Conclusion

This paper describes the evaluation of a unique implementation process of the nationwide RSE program. The baseline results showed that there was a large variation in starting positions of the implementation process among the different centers and hospitals. All professionals had a positive attitude towards the RSE program, which is an important factor for a successful implementation process (Fleuren et al. 2004). Data collection of the process evaluation is ongoing until December 2015. The results of this study will be used to improve and optimize further dissemination of the RSE program.

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Barriers and facilitators of sports participation in people with visual impairments

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Abstract *Purpose:* The purpose of this study was to determine factors influencing sports participation in people with visual impairments by comparing barriers and facilitators of sports experienced by active and inactive participants. We also determined which variables had a significant influence on participation in sports. *Methods:* People with visual impairments registered at Royal Dutch Visio, and the Eye Association were approached to complete a (telephone or online) questionnaire. The self-constructed questionnaire assessed personal and environmental barriers and facilitators of sports participation of people with visual impairments. *Results:* Six-hundred-forty-eight participants (13%) completed the questionnaire. The mean age of these participants was 49.1 (18) years, 52% were female and 63% participated in sports. Walking (43%), fitness (34%) and cycling (34%) were frequently mentioned sports. Costs, lack of buddies and the visual impairment were negatively associated with sports participation, while higher education and use of computer (software) were positively associated with sports. Most important personal barrier was the visual impairment; transport was most important environmental barrier. Active participants also mentioned dependence on others as a personal barrier. Most important personal facilitators were health, fun and social contacts; support from family was most important environmental facilitator. *Discussion:* Health professionals should try to decrease barriers such as problems with transport, lack of information and lack of sports buddies prior to the start of sports programs. The emphasis in a sports program should be on positive aspects of sports, such as fun, health and social contacts, to successfully improve sports participation in people with visual impairments.

Barriers and facilitators of sports in children with physical disabilities: a mixed method study

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Abstract This study analyzed barriers and facilitators of sports participation for children with physical disabilities (8-20 years), their parents and health care professionals. Thirty children and 38 parents completed a questionnaire, and 17 professionals were interviewed in a semi-structured way, after which the results were combined in a mixed method design. Facilitators were health, fun and social contacts. Children specifically experienced dependency on others as a barrier, parents did not have enough information about sports facilities, and professionals observed that the family's attitude had influence on the child's sports participation. Sports participation by children with physical disabilities is a complex phenomenon because such children, their parents and professionals reported different barriers. Sports participation is more physically challenging for children with severe physical disabilities, as their daily activities already require much energy. However, the psychosocial benefits of sports are applicable to all children with physical disabilities.

Keywords children with physical disabilities; sports participation; mixed methods design

Introduction

In the Netherlands in 2007, approximately 255,000 children (8%) between the ages of 6 and 19 years had a physical disability (Statistics Netherlands, 2013;The Netherlands Institute for Social Research, 2012). These children often participate less in sports than children without physical disabilities (Maher et al., 2007;van den Berg-Emons et al., 1995). The benefits of sports have been documented frequently and generally include increases in health and physical fitness and decreases in secondary conditions, such as type 2 diabetes and obesity (Heath and Fentem, 1997;US Department of Health and Human Services, 2010). These benefits are also very much applicable to children with physical disabilities (Durstine et al., 2000). To our knowledge, no study has combined the experiences of children, their parents and health care professionals on the barriers and facilitators of sports in the same study. By combining results from children, their parents and their health care professionals into one study, i.e., triangulation, a more comprehensive insight into barriers and facilitators of sports participation can be provided than

one study could do alone(Tashakkori and Teddlie, 2003). This study therefore aimed to provide comprehensive information about the barriers and facilitators of sports participation for children with physical disabilities by triangulating data from children, their parents and their health care professionals.

Methods

Subjects

Between June and December 2012, children between 8 and 20 years old were invited to participate in this study. All children were registered at the Prince Johan Friso Mytylschool, a special school for children with physical disabilities, some of whom also have mental disabilities. During that same period, parents of these children and health professionals were also invited to participate.

Quantitative section

Children and their parents were invited by mail to participate in the study by completing a questionnaire, consisting of 18 items and 23 items respectively. The questionnaires were adapted from a questionnaire for Paralympic athletes published previously (Jaarsma et al., 2013), and contained items about sports participation, disabilities, and barriers and facilitators of sports participation.

Qualitative section

The qualitative portion of the study involved semi-structured interviews with teachers and health professionals. The interviews consisted of open-end questions about the children's participation in sports both during and after school, observed barriers and facilitators of participation in sports and the professional's role in stimulating in the children's participation in sports.

Mixed methods design

This study used a mixed methods design, where qualitative and quantitative data were collected simultaneously. A mixed methods design combines two or more research methods (into one study, after which results are triangulated (Tashakkori and Teddlie, 2003).

Data collection and analysis

For the quantitative part of this study, chi-square tests were used to determine differences in barriers and facilitators between active and inactive children, and a McNemar test was used to determine differences between the children and their parents. A Mann Whitney U test was used to determine differences in the number of experienced barriers and facilitators between active and inactive children. The alpha level for statistical significance was set at 0.05 for all tests in this study. For the qualitative part of this study, the audio taped interviews were transcribed verbatim. This study followed interpretative, thematic analysis of the interviews focusing on barriers and facilitators of participation in sports.

Results

Thirty children and 38 parents completed the questionnaire. Seventeen health care professionals were interviewed. Ninety-six percent of the children participated in sports at school and 77% also participated in sports after school. Twenty-six pairs of child and parent data were obtained. The

mean age (SD) of the children was 14.1 (2.9) years old, 58% were boys, and 67% of the children had cerebral palsy. The most commonly practiced sports were swimming, cycling and football. Personal barriers were disability and fatigue; environmental barriers were lack of possibilities, transport and dependency of others. Health and fun were personal facilitators, while social contacts and support from family were environmental facilitators.

Conclusion and discussion

This mixed methods study found that children, their parents and health care professionals considered different factors as influencing the participation in sports by children with physical disabilities. Perceived barriers seemed to differ by group, suggesting that sports participation is a complex phenomenon. Sports might be more physically challenging for children with severe physical disabilities, as their daily activities already take much energy. However, the psychosocial benefits of sports are applicable to children with all types and severities of physical disabilities and should be emphasized by physicians when advising children with physical disabilities about sports. Advice about sports participation should be considered very carefully and should be tailor made.

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A study on leisure time among disabled university students with emphasize on physical activity

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Abstract *Purpose:* Leisure time is an opportunity for individuals to have an intellectual or entertaining activity according to their interests, when they are free from work, gatherings or family responsibilities. This study was performed with the aim to identify students' interests and tendencies as well as their information about facilities of the University. *Methods:* The method of this study was that the questionnaire was distributed among students with disabilities and analyzed the obtained data. *Results:* The results showed that the leisure time situation among disabled students is not good. Also showed that, disabled students have considerable leisure time, but sport a special place among the group does not fill the leisure time. *Conclusions:* The main problem for the most efficient use of leisure time is financial hardship. Other problems for students with disabilities to exercise are transportation, fear of injury, lack of suitable places for the exercise, physically problems, inaction, lack of motivation, thinking of others and distance.

Model and measurement studies on stages of prosthetic gait

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Abstract *Purpose:* To investigate principles of transfemoral amputee prosthetic gait, we studied four specific stages of prosthetic gait, namely gait initiation, weight bearing, prosthetic limb swing and gait termination. We investigated how the center of mass velocity build up is influenced by the differences in propulsive components in the limbs and how the trajectory of the center of pressure differs from the center of pressure trajectory in healthy subjects. Also, we studied the differences in the external knee moments during gait initiation with the sound limb leading and the prosthetic limb leading. Further, we explored the hip torque principle and the static ground principle as object avoidance strategies. And finally, we investigated how leading limb angles combined with active ankle moments of a sound ankle or passive stiffness of a prosthetic ankle, influence the center of mass velocity during the single limb support phase in gait termination. *Methods:* We used several two dimensional inverse and forward dynamics mathematical models and motion data of transfemoral amputee subject and able-bodied subjects using a kneewalker prosthetic device. The data were used to validate the models. *Results:* The data show that is impossible to walk symmetrically with a mechanical prosthetic limb, unless additional efforts are made to compensate for the shortcomings in the prosthetic limb; The sound limb dependency is an important strategy during gait initiation and termination. Also, the findings predict which strategies contribute to successful prosthetic limb forward swing and what should be taken into account during obstacle avoidance. *Conclusions:* The predictions, outcomes and insights gained from our model and measurement studies contributed to the development of our theory about asymmetry, functional ability and learning. We expect that improving functional ability, instead of minimizing asymmetry, will contribute to the improvement of the patient satisfaction.

Keywords transfemoral amputee, mechanical prosthetic limb, mathematical modeling, biomechanics, gait

Introduction

In the thesis 'Model and measurement studies on stages of prosthetic gait' *, we used several two dimensional inverse and forward dynamics mathematical models to investigate principles of transfemoral amputee prosthetic gait. For four specific stages of prosthetic gait, namely gait initiation, weight bearing, prosthetic limb swing and gait termination, mathematical models were designed which allowed us to conceptually analyze phenomena observed in the real world. The outcome of the models were used to make predictions about certain choices in strategies that can be made when using prosthetic limbs. Data of transfemoral amputees and able-bodied subjects using a kneewalker prosthetic device were used to validate the models, which were all checked for (internal) consistency, conservation of energy and unrealistic values. The four stages that were studied are described in separate chapters in this thesis.

Gait initiation

During prosthetic gait initiation transfemoral amputees control the spatial and temporal parameters which modulate the propulsive forces, the positions of the center of pressure and the center of mass. Whether their sound limb or prosthetic limb is leading, the transfemoral amputees reach the same end velocity. We wondered how the center of mass velocity build up is influenced by the differences in propulsive components in the limbs and how the trajectory of the center of pressure differs from the center of pressure trajectory in healthy subjects. Seven transfemoral subjects and eight able-bodied subjects were tested on a force plate and on an eight meter long walkway. On the force plate, they initiated gait two times with their sound limb leading and two times with their prosthetic limb leading. Force data were used to calculate the center of mass velocity curves in horizontal and vertical directions. Gait initiated on the walkway was used to determine the limb preference. We hypothesized that because of the differences in propulsive components, the motions of the center of pressure and the center of mass have to be different, as ankle muscles are used to help generate horizontal ground reaction force components. Also, due to the absence of active ankle function in the prosthetic limb, the vertical center of mass velocity during gait initiation may be different when leading with the prosthetic limb compared to when leading with the sound limb. The data showed that whether the transfemoral subjects initiated gait with their prosthetic limb or with their sound limb, their horizontal end velocity was equal. The subjects compensated the loss of propulsive force under the prosthesis with the sound limb, both when the prosthetic limb was leading and when the sound limb was leading. In the vertical center of mass velocity a tendency for differences between the two conditions was found. When initiating gait with the sound limb, the downward vertical center of mass velocity at the end of the gait initiation was higher compared to when leading with the prosthetic limb. Our subjects used a gait initiation strategy that depended mainly on the active ankle function of the sound limb; therefore they changed the relative durations of the gait initiation anticipatory postural adjustment phase and the step execution phase. Both limbs were controlled in one single system of gait propulsion. The shape of the center of pressure trajectories, the applied forces and the center of mass velocity curves are described in this chapter.

Weight bearing

In this study, the occurrences of stabilizing and destabilizing external moments of force on a prosthetic knee during stance, in the first steps after gait initiation, in inexperienced users were investigated. Primary aim was to identify the differences in the external moments during gait initiation with the sound limb leading and the prosthetic limb leading. A prosthetic limb simulator device, with a flexible knee, was used to test able-bodied subjects, with no walking aid experience. Inverse dynamics calculations were performed to calculate the external moments. The subjects learned to control the prosthetic limb within 100 steps, without walking aids, evoking similar patterns of external moments of force during the steps after the gait initiation, either with their sound limb loading or prosthetic limb leading. Critical phases in which a sudden flexion of the knee can occur were found just after heelstrike and just before toe off, in which the external moment of force was close to the internal moment produced by a knee extension aiding spring in the opposite direction.

Prosthetic limb swing

In this study, conditions that enable a prosthetic knee flexion strategy in transfemoral amputee subjects during obstacle avoidance were investigated. This study explored the hip torque principle and the static ground principle as object avoidance strategies. A prosthetic limb

simulator device was used to study the influence of applied hip torques and static ground friction on the prosthetic foot trajectory. Inverse dynamics was used to calculate the energy produced by the hip joint. A two-dimensional forward dynamics model was used to investigate the relation between the obstacle-foot distance and the necessary hip torques utilized during obstacle avoidance. The study showed that a prosthetic knee flexion strategy was facilitated by the use of ground friction and by larger active hip torques. This strategy required more energy produced by the hip compared to a knee extension strategy. We conclude that when amputees maintain sufficient distance between the distal tip of the foot and the obstacle during stance, they produce sufficiently high, yet feasible, hip torques and use static ground friction, the amputees satisfy the conditions to enable stepping over an obstacle using a knee flexion strategy.

Gait termination

In this study we investigated how leading limb angles combined with active ankle moments of a sound ankle or passive stiffness of a prosthetic ankle, influence the center of mass velocity during the single limb support phase in gait termination. Also, we studied how the trailing limb velocity influences the center of mass velocity during this phase. We analyzed force plate data from a group of experienced transfermoral amputee subjects using a prosthetic limb, and the outcome from a two dimensional mathematical forward dynamics model. We found that when leading with the sound limb, the subjects came almost to a full stop in the single limb support phase, without the use of the prosthetic limb. When leading with the prosthetic limb, the center of mass deceleration was less in a relatively short single limb support phase, with a fast forward swing of the trailing sound limb. Slowing down the heavier trailing sound limb, compared to the prosthetic limb, results in a relatively larger braking force at the end of the swing phase. The simulations showed that only narrow ranges of leading limb angle and ankle moments could be used to achieve the same center of mass velocities with the mathematical model as the average start and end velocities of the prosthetic limb user. We conclude that users of prosthetic limbs have a narrow range of options for the dynamics variables to achieve a target center of mass velocity. The lack of active control in the passive prosthetic ankle prevents the transfermoral amputee subjects from producing sufficient braking force when terminating gait with the prosthetic limb leading, forcing the subjects to use both limbs as a functional unit, in which the sound limb is mostly responsible for the gait termination.

Discussion and conclusion

In contrast to other researchers, who suggest that it would be of benefit to develop a uniform, robust modelling strategy for both research and clinical rehabilitation practice, it is my opinion that specialised, custom-developed mathematical models can be used to model phenomena that occur in the real world. Based on Occam's razer principle, we used models that were relatively simple with only limited assumptions, to investigate the principles of transfemoral amputee prosthetic gait.

It should be taken into account that when we want to use these models to make predictions about the four phases of gait in for example the clinical setting, one more important step has to be made in the research process. The validity and usability of our models in both the conceptual and real world have to be verified further by (learning) experiments with transfemoral amputees or with able-bodied subjects using a prosthetic limb simulator device in various conditions, with various (microprocessor controlled) prosthetic components and properties in various environments.

The predictions, outcomes and insights gained from our model and measurement studies contributed to the development of our theory about asymmetry, functional ability and learning, and also formed our ideas about trunk motions and microprocessor controlled limb limbs prosthetics. Based on our findings, we concluded that it is impossible to walk symmetrically with a mechanical prosthetic limb, unless additional efforts are made to compensate for the shortcomings in the prosthetic limb. We expect that improving functional ability, instead of minimizing asymmetry, will contribute to the improvement of the patient satisfaction. According to the principles of Discovery Learning and learning as a function of attentional focus, improving the functional ability can best be achieved by training in environments which enable the transfemoral amputee to find individual optimal performance patterns for complex motor skills.

The thesis is part of a series of theses (1; 2; 3) resulting from the project 'Postural control after lower limb amputation; changes in body representation and the recovery in postural control'. The project is the result of a collaboration between the Center for Rehabilitation Medicine of the University Medical Center Groningen, the Netherlands and the Center for Human Movement Sciences of the University Medical Center Groningen, University of Groningen, the Netherlands. This integrated approach unites two types of research: research from a clinical science approach and research from an fundamental sciences approach. The clinical research was performed by medical specialist for rehabilitation Aline H. Vrieling. Her thesis (2009) formed the base for the current thesis. Many of the findings that were reported in her thesis were studied from a biomechanics perspective in this part of the project. Parts of the datasets that were reported in her thesis were also used in the current thesis.

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Prosthetic lower limb; feedback and control

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Abstract Transfemoral amputees experience high levels of difficulty in maintaining static and dynamic balance on their prosthetic limb. For adequate control of the limb, not only are muscle forces and sensory feedback essential, but also the speed with which the forces are applied and the limb is controlled. In a recent study a custom-made device transmitting real-time proportional feedback was used to explore the possible contributions of non-conventional feedback to prosthetic limb control. Feedback from pressure sensors located under a prosthetic foot was provided via vibrating tactors located proximally on the thigh. Although not part of the original research question, some results of this study suggest that the use of vibratory feedback leads to improvements in fast open-loop mechanisms of postural control in prosthetic limb users.The ability to rapidly shift the center of gravity when initiating motion increases when vibratory feedback is applied. This finding suggest that an efficient preemptive feedforward mechanism, i.e. sensorimotor adaptation, is used during repetitive or predictable motor tasks. Based on this study, it seems that in addition to the information provided by the forces on the stump during the interaction with the socket, extra vibratory feedback may be of benefit to improve the functional ability of the prosthetic limb user. Further research is warranted to investigate this apparent directionally dependent interaction.

The effects of rear wheel camber on the physiological and biomechanical responses of able-bodied participants

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Abstract The purpose of this study was to investigate the effects of rear wheel camber on physiological and biomechanical responses during sub-maximal wheelchair propulsion. Able-bodied participants (N = 8) with no prior experience in wheelchair propulsion undertook a three-week familiarization period followed by a single testing session in four different camber settings (15°, 18°, 20°, 24°) on a motor driven treadmill. A SMART^{Wheel} collected kinetic data and temporal parameters during the first and final familiarization trial, and during the camber testing session. Oxygen uptake (VO_2), heart rate (HR), and rating of perceived exertion (RPE) responses were also collected. A one-way ANOVA with two repeated measures was conducted on familiarization data and a repeated measure ANOVA was conducted on all camber testing data. Localized RPE, overall RPE, HR and VO_2 all showed a significant decrease between the first and final familiarization session ($p = 0.0001$; $p = 0.002$; $p = 0.043$; $p = 0.003$), whilst increases were observed for push time ($p = 0.0001$) and push angle ($p = 0.0001$). Stroke frequency and the rate of force development ($p = 0.013$; $p = 0.006$) both decreased between the two sessions. Localized RPE was found to be lower at a camber setting of 18° (9 ± 1, $p = 0.031$) and 20° (9 ± 1, $p = 0.031$) compared to 24° (10 ± 2). No changes in any other physiological or biomechanical variables were observed between camber settings. Adaptation and familiarization to wheelchair propulsion technique occurred over the three-week familiarization period with 18° camber perceived to be the most economical by able-bodied participants. These findings may have implications for the less experienced ambulant wheelchair basketball player when choosing their initial chair set-up.

Keywords Wheelchair configuration, sports wheelchair propulsion

Introduction

Rear wheel camber, defined by Higgs (1983) as 'the angle of the main wheels in relation to the vertical' has a direct effect on mobility performance. Many wheelchair athletes select greater camber as they believe it has a favourable influence on maneuverability performance. Consequently, for optimum wheelchair setup, rear wheel camber has therefore become a considerably important variable. Much of the literature has looked at rear wheel cambers between 0° to 15°, however wheelchair athletes who participate in competitive court sports (e.g. basketball and rugby) tend to use wheelchairs with cambers ranging from 15° to 24°. Previous

investigations into rear wheel camber have tended to incorporate inexperienced able-bodied participants, as they are a more homogenous population (Veeger et al, 1989; Buckley & Bhambhani, 1998; Perdios et al., 2007). Responses from able-bodied, non-wheelchair users have been found to fully comply with the overall trends in physiology shown by wheelchair users and sportsmen (Lenton et al., 2008). The physiological and biomechanical responses elicited during wheelchair propulsion for rear wheel cambers ranging from 15° to 24° has only been identified in an elite wheelchair athlete population (Mason et al., 2010). No study has described the effects that using relevant sport specific camber configurations has on hand rim forces. The aim of this present study was therefore to examine the effect of four different camber settings (15°, 18°, 20° and 24°) on the physiological and biomechanical responses shown during sub maximal exercise, in particular the hand rim forces and mechanical efficiency.

Methods

Participants

Eight males (age 22 ± 1 years; mass 81.3 ± 6.4 kg) volunteered to participate in the present study. All were able bodied and had no prior experience of pushing a wheelchair.

Variables

A three-week twice weekly familiarization study was undertaken by all participants, followed by a single testing session all in an adjustable sport wheelchair (Top End Transformer, Invacare). The following variables were measured in four camber settings (15°, 18°, 20° and 24°).

- Physiological variables: Heart rate (HR), localized, centralized and overall rating of perceived exertion (RPE), oxygen uptake (VO_2), respiratory exchange ratios and gross mechanical efficiency.
- Biomechanical variables: Push angle, push time, stroke frequency, mean power output (PO), mean work per cycle, the resultant and tangential force applied to the hand rim and the rate of force development.

Statistics

A one-way ANOVA with two repeated measures was applied to the familiarization study results to examine differences between the first and last session. Differences between the camber settings during the single testing session for all physiological and biomechanical variables were examined using a repeated measures ANOVA. Pairwise comparisons were used to explore any significant main effects. A statistically significant difference was represented by $P < 0.05$.

Results

Localized RPE, overall RPE, HR and VO_2 all showed a significant decrease between the first and final familiarization session ($p = 0.0001$; $p = 0.002$; $p = 0.043$; $p = 0.003$ respectively), whilst increases were observed with push time ($p = 0.0001$) and push angle ($p = 0.0001$). Stroke frequency and the rate of force development ($p = 0.013$; $p = 0.006$) both decreased between the two sessions. Localized RPE was found to be lower at a camber setting of 18° (9 ± 1, $p = 0.031$) and 20° (9 ± 1, $p = 0.031$) compared to 24° (10 ± 2). No significant changes in any other physiological or biomechanical variables were observed between camber settings. Although not significant, 15° camber resulted in the highest PO (22.4 ± 4.6), HR (88 ± 9) and VO_2 (0.92 ± 0.11) values. 18° camber resulted in the lowest HR (86 ± 9) and VO_2 (0.88 ± 0.07) values.

Conclusion and discussion

Adaptation and familiarization to wheelchair propulsion occurred across a number of physiological and biomechanical variables over the three-week period. 15° camber resulted in the highest power output, but also the highest VO_2 and HR. This reduction in economy therefore leads to the conclusion that 15° may not be the most economical camber setting for able-bodied participants with little wheelchair experience. VO_2 and HR were identified to be lowest at a camber of 18°, suggesting that this camber setting provides the most economically efficient propulsion when looking at able-bodied participants. It could therefore be recommended for use at sub-maximal levels of exercise. The absence of significant responses shown between the camber settings prevented one camber to be selected as optimal. This was likely due to the conclusion that adaptation and familiarization was still occurring during the sub-maximal testing session, and therefore improvements in propulsion variables were still being made.

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BOT-2 Revised: Assessment Accommodations for Children and Youth with Intellectual Disabilities

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Abstract The purpose of this study was to determine reliability using a revised BOT-2. The suggested revision incorporated a reduced number of test items gleaned from three original BOT-2 categories. Also integrated into the revised BOT-2 was an enhanced prompting and cueing strategy, i.e., verbal directions and demonstrations, referred to as the familiarization protocol (FP). Forty-eight youths (age = 13.6 ± 3.6 years; 31 males, 17 females) with intellectual disabilities (ID) performed eight items from the BOT-2 on two different days with 3 to 4 weeks between test administrations. Individual assessments were conducted in a clinical setting. The items that were tested reflected three BOT-2 categories, namely, bilateral coordination, balance, and upper-limb coordination. Significant ($p < .05$) intraclass correlation coefficients were observed for 7 of the 8 tests, and Cronbach's alpha indicated five tests to be acceptable to excellent (>.6), one test poor (.506), and two tests unacceptable (<.4) for reliability of test scores. The rev-BOT-2 improved reproducibility and reliability in evaluating bilateral coordination, balance, and upper-limb coordination in children and youth with ID. Utilization of the FP provides a more accurate estimation of participants' performance which, in turn, will provided teachers and clinicians with a more reliable baseline from which to plan and conduct programs of education and rehabilitation.

Keywords Assessment, Intellectual Disability, Motor Proficiency

Introduction

The BOT-2 (Bruininks & Bruininks,2005) is a widely used instrument that has been validated for use with children with developmental coordination disorder, mild to moderate intellectual disability, and high functioning autism or Asperger's syndrome (Cools, DeMartelaer, Samaey, & Andries, 2009). Recent work in the physical therapy laboratory at Wichita State University using the test methodology established by the BOT-2 has demonstrated unacceptable to fair reliability and concordance between tests when used with individuals with intellectual disabilities (Barnes, Fuller, Michael, Nola, Stevens, & Pitetti, 2012). Therefore, the purpose of this study was to determine reliability with a revised BOT-2 using a reduced number of test items selected from three of the original BOT-2 categories, namely, bilateral coordination, balance, and upper-limb coordination. The revised BOT-2 also introduced an enhanced prompting strategy using a system of least prompts referred to as the familiarization protocol.

Methods

Forty-eight youths (age = 13.6 ± 3.6 years; 31 males, 17 females) with intellectual disabilities (ID) performed eight items from the BOT-2 on two different days with 3 to 4 weeks between test administrations. Individual assessments were conducted in a clinical setting. The items that were tested reflected three BOT-2 categories, namely, bilateral coordination, balance, and upper-limb coordination.

Results

Significant (p < .05) intraclass correlation coefficients were observed for 7 of the 8 tests, and Cronbach's alpha indicated five tests to be acceptable to excellent (>.6), one test poor (.506), and two tests unacceptable (<.4) for reliability of test scores (see Table 1).

Table 1. Reliability coefficients for Revised BOT-2

Item	Test 1	Test 2	R_2/ICC
Nose touching (n=48)	3.8 ± 0.7	3.8 ± 0.7	.401 (Unacceptable)* .250 (-.03-.050) (p<.05) (Poor)**
Jumping in Place (n=47)	4.1 ± 1.6	4.1 ± 1.7	.911 (Excellent)* .836 (.72-.91) (p<.01) (Excellent)**
Finger-Foot Tapping (n=48)	9.1 ± 2.0	9.5 ± 1.7	.170 (Unacceptable)* .093 (-.194-.365) (NS) (Poor)**
Standing on Line-Eyes Closed (n=46)	7.0 ± 3.2	6.2 ± 3.3	.675 (Acceptable)* .510 (.25-.70) (p<.01) (Fair)**
Walking Heel-to-Toe (n=48)	4.1 ± 2.2	3.9 ± 2.2	.847 (Good)* .734 (.57-.84) (p<.01) (Good)**
Standing on Balance Beam (n=39)	4.7 ± 2.6	5.6 ± 7.1	.509 (Poor)* .342 (.03-.59) (p<.02) (Poor)**
Drop & Catch–Two Hands (n=46)	4.2 ± 1.4	3.7 ± 1.5	.609 (Acceptable)* .437 (.17-.64) (p<.01) (Fair)**
Dribbling-Alternate Hands (n=48)	8.1 ± 2.8	8.8 ± 2.6	.754 (Good)* .605 (.39-.765) (p<.01) (Fair-Good)**

* Cronbach's Alpha (reliability of scores of examinees)
** Intraclass Correlation Coefficient (ICC) (95%CL)

Conclusion and discussion

The rev-BOT-2 improved reproducibility and reliability in evaluating bilateral coordination, balance, and upper-limb coordination in children and youth with ID. Utilization of the Familiarization Protocol provided a more accurate estimation of participants' performance which, in turn, will provided teachers and clinicians with a more reliable baseline from which to plan and conduct programs of education and rehabilitation.

Acknowledgements

We wish to acknowledge the efforts of Ruth Ann Miller who has contributed significantly to this project.

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The effect of physical activity on circulating inflammatory markers in people with spinal cord injury

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Abstract The purpose of this systematic review was to evaluate the effect of physical activity (PA) and exercise on the acute and long-term circulatory inflammation response in people with chronic spinal cord injury (SCI). We searched Pubmed (MEDline), Embase, Central, Cinahl and PEDro, involving variations of: SCI, PA, exercise, sports, inflammation, cytokines, myokines and adipokines. No time or language restrictions were applied. Except for case reports, we included any type of study, both genders, all ages, and with SCI, resulting in 11 studies that met inclusion criteria. PA included leisure or work activity, including exercise. Two authors independently scanned titles and abstracts, and read the articles included. One author extracted, while the second double-checked the data. The methodological quality and evidence were rated by the Cochrane Risk of Bias tool or the Newcastle-Ottawa Scale, and the GRADE approach. The included studies had a high risk of bias and 'very low' levels of evidence . Meta-analyses were performed (random effects model or generic inverse variance method). The acute interleukin 6 (IL-6) response to exercise was not different between SCI and able-bodied individuals (p=.91), however, responses were higher in paraplegia (PP) than in tetraplegia (TP), WMD 1.19, p<.00001 and 0.25, p=0.003, respectively). Physically active people with SCI had a lower plasma C-reactive protein (CRP) (WMD -0.38, p=.009). The CRP was lower post- than pre-exercise intervention (WMD -2.76, p=.0001). No acute effects to exercise were found in CRP, Tumour Necrosis Factor alpha (TNF-α) and Interleukin 1 receptor antagonist (IL-1ra), while long-term effects suggested reduced IL-6 and TNF-α. It can be concluded that exercise may improve low-grade inflammation under influence of IL-6 and CRP. The stronger change of IL-6 and CRP in PP than in TP suggests a sympathetic nervous system regulatory role. However, the evidence level was very low.

Keywords Inflammation markers, physical activity, spinal cord injury, paraplegia, tetraplegia

Introduction

Factors that promote systemic low-grade inflammation as expressed in higher levels of circulating inflammation markers, seem to be increased in people with SCI compared to non-SCI (Davies, Hayes et al. 2007). Low-grade inflammation is linked to inflammatory responses that occur in

considerable numbers of people with SCI and is a potential contributor to mortality and co-morbidity. Including a greater risk for cardiovascular disease (CVD) and respiratory disease, the two leading causes of death among people with SCI (DeVivo, Rause et al. 1999).

Evidence in healthy able-bodied people suggests that PA and exercise are related to a decreased risk of developing chronic diseases such as CVD and respiratory disease by way of reducing levels of circulating markers of inflammation (Gleeson, Bishop et al. 2011). A decreased risk for CVD is seen with increased levels of PA and fitness showing lower levels of CRP. The long-term anti-inflammatory effect in the blood circulation associated with PA may be related to a down-regulation of immune cell release of pro-inflammatory cytokines such as IL-6, tumour necrosis factor alpha (TNF-a) and CRP, and an up-regulation of anti-inflammatory cytokine release, such as interleukin 1 receptor antagonist (IL-1ra) and interleukin 10 (IL-10) (Archer, Fredriksson et al. 2011). The aim of this systematic review is to evaluate the effect of PA and exercise on the acute and long-term circulatory inflammation response in people with chronic SCI.

Methods

Search strategy, data collection and analysis

We included any type of study, except for case reports, with participants of both gender, of all ages and with either acute or chronic PP or TP (≥ 1 year post-SCI). PA consisted of leisure or work activity, including exercise. We searched Pubmed (MEDline), Embase, CENTRAL, Cinahl and PEDro databases, including articles up to March 19th, 2013. No time or language restrictions were applied and the strategy included MeSH headings and involving variations of the keywords. Two review assessors independently scanned the titles and abstracts before reaching consensus over the final articles that were included. One author extracted, while the second double-checked the data. Meta-analysis were performed (random effects model or generic inverse variance method). Study data were tested on heterogeneity by the eye-ball test (evaluating overlapping confidence intervals), applying a test for homogeneity (Q), and quantifying the heterogeneity (I^2).

Assessment of risk of bias and level of evidence

The risk of bias of the articles was assessed by using the Cochrane Risk of Bias tool in case of prospective controlled trials and the Newcastle-Ottawa Scale (NOS) in case of observational studies. The overall strength of evidence was evaluated by using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.

Results

In this review we retrieved 2037 articles, which resulted in 11 included studies, and involved 328 participants (age rang was 22 to 70 yrs.). The studies included 3 prospective controlled trials, 5 cross-sectional studies and 3 case-series. The type of PA and exercise interventions, and the SCI groups (TP, PP or both) varied widely. The outcome measures of PA on the acute circulating inflammatory response were IL-6, IL-1ra, CRP and TNF-α. The long-term outcome measures were Il-6 and CRP. The risk of bias for the prospective controlled trials and cross-sectional judged high and the level of the total quality of the included studies was considered low.

Baseline IL-6 was significantly higher in persons with chronic SCI, (2.18±0.44 pg/ml) compared to able-bodied participants. Though, significant increases in circulating IL-6 were seen during, immediately after and 2 hours after exercise in both groups. However, no significant circulatory IL-6 changes were detected in the TP group. In addition, we were able to retrieve two groups of

PP to perform a subgroup analysis. The WMD was 1.19 pg/ml, with a 95% CI of 1.11 to 1.28 (p<0.001), with no heterogeneity, indicating an increase of IL-6 post exercise compared to pre-exercise. We were also able to retrieve two TP groups with a pre- and post exercise comparison. The pooled WMD was 0.25 pg/ml, with a 95% CI of 0.09 to 0.42 (p = 0.003), while the heterogeneity was negligible (I^2 = 14 %). No effect on IL-10 was detected in all groups in response to exercise. However, base levels of IL-10 were higher in the TP and PP groups compared to the non-SCI group (p=.001). In addition, no significant interaction effects or main effects of group or time for plasma concentrations of IL-1ra and TNF-α were found. There was substantial heterogeneity. The effect of PA on circulatory CRP (3 cross-sectional studies, N= 47) had a WMD of -0.38 mg/L; CI of -0.67 to -0.09 (p=0.009) indicating an inverse association of PA with CRP. The long-term effect of exercise in participants with SCI only, without a control group, resulted in a WMD of -2.76; 95% CI -4.19 to -1.34 (p=0.0001). This suggests an inverse relation-ship between long-term exercise (≥60% of VO_2 max, ≥ 3 x per week and ≥ 12 weeks) and CRP in SCI.

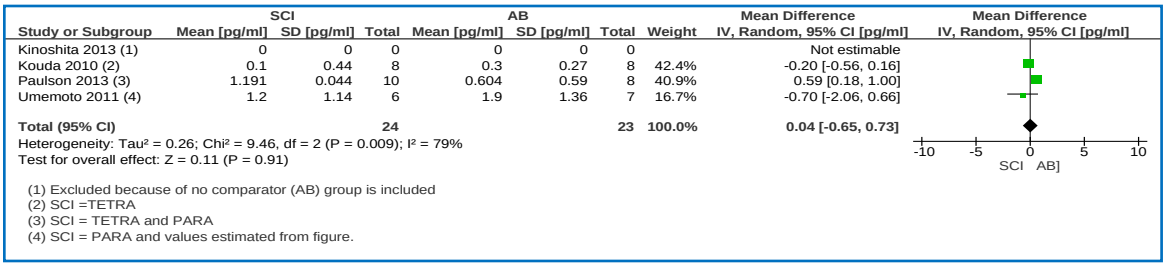

Figure 1. Acute IL-6 response in SCI versus able bodied participants compared to pre-exercise

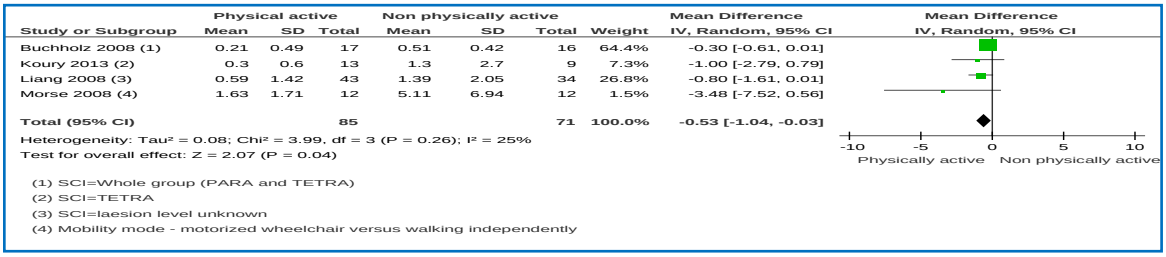

Figure 2. CRP in physically active versus physically inactive participants including mode of mobility (cross-sectional).

Conclusion and discussion

Although, the quality of evidence to reduce the risk of pulmonary disease and CVD in SCI by reducing low-grade inflammation through exercise is very low, and the base levels of IL-6, CRP and IL-10 in SCI were high compared to AB, the findings suggest a significant increase in circulating IL-6 directly after moderate to vigorous exercise for individuals with SCI. The effects of long-term exercise suggest a significant association and effect between PA and a reduction of circulating CRP, and some indication of IL-6 and TNF-α plasma reduction. In addition, there does not seem to be a difference in individuals with SCI compared to able bodied individuals in the response of circulating inflammatory markers to exercise. The exercise response appears to be stronger in individuals with PP, with conflicting results for individuals with TP, suggesting a possible regulatory role of the sympathetic nervous system in the circulating inflammation response. However, further research of higher methodological quality is needed.

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Rolling resistance and propulsion efficiency in manual and power-assisted wheelchair propulsion

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Abstract *Purpose:* The present study investigated the differences in rolling resistance, propulsion efficiency and energy expenditure required when using different wheelchair types (manual, power-assisted and extra-power-assisted) and tire pressures. A key point was to determine the effect of different levels of motor assistance provided by the wheelchair. *Methods:* Ten able bodied individuals participated in a treadmill drag test, using manual and power-assisted wheelchairs at three inflation levels (50%, 75%, 100%) to determine drag force in each configuration. Additionally, the participants performed three 6-min propulsion sets: one with manual (M), one with power-assisted (PAW) and one with extra-power assisted (EP) wheelchairs. During the propulsion, energy consumption was calculated as a function of the VO_2 and RER measured with a portable gas analyzer. Propulsion efficiency was subsequently calculated for the same power output for all participants. *Results:* Drag force levels varied significantly in different tire inflation conditions (50%, 75%, 100%) in M and PAWs, the latter, along with the 50% inflation condition, showing the highest drag force levels. The use of EPs appeared to be significantly superior in terms of both propulsion efficiency and energy expenditure required by the user. *Conclusions:* Power-assisted wheelchairs, being heavier than manual ones, are subject to higher levels of rolling resistance. Their use can increase propulsion efficiency and decrease the energy input required by the user, but only if the motor delivers sufficient support to surpass the effect of increased rolling resistance. Deflated tires also increased resistance to propulsion, so tire maintenance is advisable to avoid unnecessary strain.

Effects of a High Intensity Aerobic Training in Chronic Stroke Patients: Mechanisms for Improvements in Oxygen Consumption

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Abstract.The first aim of the study was to investigate the physiological effects of a high intensity aerobic training in chronic stroke patients. The second aim was to understand the mechanisms of adaptation in oxygen consumption (VO_2peak) that occur with a three-month aerobic training in this population. Six chronic stroke performed a three-month high intensity treadmill training. The subjects were evaluated before starting the training (T0) and after the end of the training (T1). The assessments consisted in: peak oxygen consumption (VO_2peak). During the VO_2peak test, were evaluated central factors: cardiac output (CO) by using Portapres, and peripheral factors: oxyhemoglobin (HbO_2) and deoxyhemoglobin (Hb) by using near infrared spectroscopy (NIRS) on both legs. The training mode was uphill treadmill walking in 5x5 minute interval training at 95% VO_2peak. RelativeVO_2peak increased from a mean of 18.6 ± 2.7 ml/kg/min to 24.8 ± 4.8 ml/kg/min. Absolute VO_2peak increased from a mean of 1630 ± 300 ml/kg to 2115 ± 377 ml/min. CO didn't change significantly. Peripheral factors didn't change significantly in the healthy side meanwhile in the paretic side only the deoxyhemoglobin increased significantly, from a mean of 22.1 to 26.8 (μM). Correlation between VO2peak (ml/kg/min) and CO (l/min) was not found. Correlations between changes healthy side peripheral factors and VO2peak (ml/kg/min) were not found. A great correlation between VO2peak (ml/kg/min) and change in deoxyhemoglobin (μM) in paretic side was found (r=.95).

Keywords High Intensity Aerobic Training, Treadmill, Oxygen Consumption, Chronic Stroke, Hemiplegia

Introduction

Stroke is a major cause of chronic disability worldwide. After stroke, patients continue to live with residual physical impairments (reduced mobility, poor balance and muscle weakness) which may lead to physical inactivity and sedentary life. Physical activity is positively related to physical function and cardiorespiratory fitness, which is reflected by aerobic capacity *(Brazzelli, Saunders et al.2011)*. Aerobic capacity is the product of the cardiac output and the arterial- venous oxygen difference. Both these parameters in stroke patients are decreased *(Pang, Eng et al. 2006)*. Exercise has been shown being a potent physiological stimulus, which can cause many adaptations *(Billinger, Coughenour et al. 2012)*. In the literature, the importance of aerobic training in order to improve aerobic capacity has been reported and the possibility to train chronic stroke patients with high intensity (80-90% HRR) has been shown *(Pang, Eng et al. 2006)*.

Despite of the positive effects of high intensity training in stroke patients there is a lack of knowledge regarding the central and peripheral mechanisms involved in oxygen transport and utilization. The first aim of the study is to assess the effects of a high intensity aerobic training in improving cardiorespiratory fitness in chronic stroke patients. The second aim is to understand the mechanisms of adaptation to changes in VO_{2peak} that occur with a training period among this population.

Methods

Six chronic stroke subjects were recruited. The characteristics of the subjects are summarized in the Table 1. All of them were initially diagnosed with rest electrocardiography (ECG) and effort ECG. The patients fulfilling the inclusion criteria were finally selected.

Table 21. Subject's characteristic

Subj #	Gender	Age (years)	Stroke Type	Paresis R/L	Onset (years)	Weight (kg)	Height (m)	BMI	Skinfolds Paretic/Healthy		VO2peak (ml/kg/min)	6MWT
1	Male	53	IS	DX	6	102	1.81	31.1	10.0	11.0	20.0	341
2	Male	62	IS	DX	8	102	1.78	32.2	13.0	14.2	18.5	227
3	Male	68	IS	SX	8	75	1.76	24.2	6.6	7.5	17.3	189
4	Male	59	IS	SX	10	77	1.66	27.9	12.3	11.5	22.5	332
5	Female	60	IS	DX	8	75	1.61	28.9	30.0	29.7	19.0	270
6	Male	62	IS	SX	10	98	1.72	33.1	16.1	18.2	14.4	222
X		**61**		**3/3**	**8.0**	**88.0**	**1.72**	**29.5**	**14.6**	**15.4**	**18.6**	**248**
SD		**5**			**1.4**	**14.0**	**0.08**	**3.3**	**8.4**	**7.5**	**2.7**	**55**

All the enrolled patients in the study were evaluated before starting the training (T0), and after the training (T1). The assessment protocol consisted in: *Peak of oxygen consumption (VO_2peak)*: breath by breath oxygen uptake was measured by using a metabolimeter (Cosmed, Quark b_2, Rome, Italy). Heart rate was measured using a Heart-rate monitor. The protocol was a modified Balke test. The subjects were allowed to hold him/herself on the treadmill handrail with one hand. The test was stopped when the subject met the criteria given by the American College of Sport medicine. (Lam, Globas et al. 2010). *Cardiac Output measurements (CO):* was measured non-invasively during incremental treadmill test, by finger photoplenthysmography (Finapres Medical System BV, Portapres, Amsterdam, Netherlands). The finger photoplenthysmography data were corrected by mean of open- circuit inert gas wash- in method (Innovision A/S, Innocor, Odense, Denmark). *Peripheral Factors – Oxyhemoglobin [HbO] and Deoxyhemoglobin [Hb]:* during the incremental test in treadmill the subjects were wearing a Near Infrared Spectroscopy (Nirox, NIRS, Brescia, Italy). The NIRS probe were placed over the vastus lateralis of the both legs, approximately 120 to 140 mm above the knee, along the vertical axis of the thigh. Subject's skin were cleaned and shaved carefully, the probes were applied directly on the skin by means of tape, and fixed using an elastic band. Before the test skinfolds in the site of the probe were collected on both side. The subjects performed a high intensity treadmill training. The mode of the training was uphill treadmill walking 5x5 mins intervals at 85% and 95% of VO_{2peak}, precede by 8-minute warm- up period on the treadmill at self- selected speed and 1% inclination. Between the 5- minute intervals, 3- minute active breaks walking at approximately 70% of VO_{2peak} was applied. The training session were terminated by a 5- minute cool-down period at 50% of VO_{2peak}.

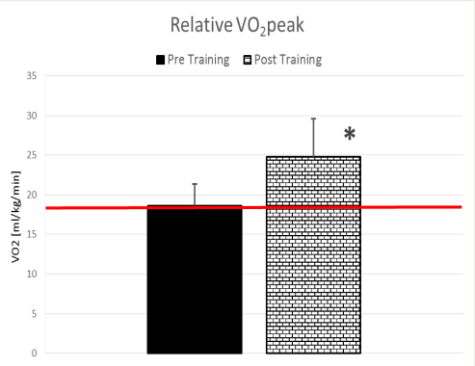
Statistics

Sample characteristics were summarized using descriptive statistics, means, standard deviations, range and median value. Differences between T0 and T1 within group were tested by mean of

Wilcoxon signed rank test. A significance level of 0.05 was adopted. Bivariate analysis were applied in order to test existing correlations between outcomes.

Results

Relative VO_2peak improved by 6.2 ± 2.8 ml/kg/min. This change was significant within the group, between pre and post- training (Figure1). Absolute VO_2peak improved by 485.4 ± 183.4 ml/min. COpeak (l/min) improved by 4.7 ± 5.2 l/min. This change was not significant within the group, between pre- and post- training. [HbO]peak (µM) in the paretic side improved by 32.0 ± 21.0 (µM), meanwhile in the healthy side this values decreased by -4.0 ± 4.2 (µM).. None on these changes was significant within the group and between pre- and post- training. [Hb]peak (µM) in the paretic side improved by 5.5 ± 3.4 (µM), meanwhile in the healthy side this value improved by 5.5 ± 10.1 (µM). The change in the paretic side was significant within the group, between pre- and post- training. Although the improvement in [HbO]peak (µM) in healthy side, the change was not significant. Improvements in VO_2peak (ml/kg/min) are not related with improvements in COpeak (l/min), r=.03. A great relation between relative VO_2peak (ml/kg/min) and [Hb]peak (µM) in the paretic side (r=.95) was found (figure 2), but the same relation with the healthy side was not found (r=.47)



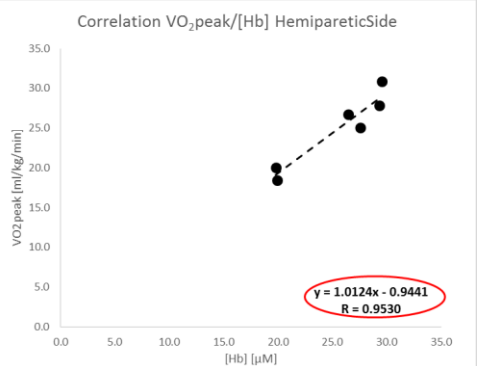


Figure 5.Relative VO_2peak: mean, standard deviation and significance

Figure 6 Correlation between outcomes: VO_2peak and [Hb]peak in paretic side

Conclusion and discussion

The study demonstrated the effectiveness of a three- month high intensity aerobic training with interval method. We suppose that in chronic stroke subjects with hemiplegia the improvements in VO_2peak (ml/kg/min) caused by high intensity interval training on treadmill are primarily due to a rise in deoxygenation in the paretic limb, caused by an increased O_2 demand.

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Physical activity levels of people with schizophrenia included in a physical activity program: a pilot study using accelerometers

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Abstract Although it is acknowledged that physical activity (PA) improves physical and mental health of people with schizophrenia, the optimal level of PA recommended for this population is not yet known. Therefore, the aim of this study was to analyze the PA levels of people with schizophrenia who participated in a PA program. Specifically, we intended to verify the differences in the level of PA between week days with sessions of PA, week days without sessions of PA and weekend days. A convenient sample of six adults (male=4, female=2) was recruited according to specific inclusion criteria. The GT3X accelerometer was used to assess the daily PA over 7 consecutive days. ANOVA test was used to analyze the level of PA, in the three moments of evaluation, according to: i) number of counts, ii) number of minutes in sedentary activities, and iii) number of minutes in moderate to very vigorous activities. The level of significance was established in $p \leq .05$. All participants achieved the guidelines (i.e., minimum of 150 min.) for PA per week (min=253.66min; máx= 510.75min.). Significant differences were found in the average number of counts/min^{-1} in the week days with PA sessions (M= 1019.58; SD=235.07) in comparison with the week days without PA sessions (M= 620.85; SD=164.09) and the weekend days (M=545.82; SD=162.24). Similarly, significant differences were found in the time spent in moderate to very vigorous activities during the week days with PA sessions (M=84.17; SD=26.80) in comparison with the week days without PA session (M=51.58; SD=15.79) and the weekend days (M=39.23; SD=23.15). No significant differences were found regarding the time spent in sedentary activities. This study highlighted the importance of structured physical activity programs to improve daily physical activity in people with schizophrenia.

Keywords schizophrenia, accelerometers, physical activity program

Introduction

Schizophrenia is a psychiatric disorder that alters the perception, thought, affection and behavior of the individual (National Institute of Mental Health [NIMH], 2009). People with schizophrenia often have risk behaviors such as physical inactivity, poor diet, alcohol and drug abuse (Von Hausswolff - Juhlin et al., 2009). Thus, this population has a higher rate of diseases (i. e., cardiovascular diseases, metabolic syndrome) than the general population (Roick et al., 2007). Researchers of this field have demonstrated the importance of physical activity (PA) schizophrenia to improve physical and mental health in people with schizophrenia (Faulkner & Biddle, 1999). Therefore, it is important to know the PA levels of this population for an adequate

prescription of exercise in accordance with the individual needs. Thus, the aim of this study was to analyze the PA levels of people with schizophrenia who participated in a PA program. Specifically, we intend to verify the differences in PA levels between days with PA sessions, days without PA sessions and weekend days.

Methods

The sample consists of 6 adults (4 men and 2 women) (M = 43.83 years; SD = 7.52 years) with schizophrenia. PA levels were assessed by the GTX3 accelerometer (Actigraph, Florida) on the right hip using an adjustable belt.

Results

By performing an individual analysis of the time spent in moderate to very vigorous physical activity (MVPA), we found that all participants performed the minimum 150 minutes per week (min = 253.66 minutes, max = 510.75 minutes).

Significant differences were found in the average number of days counts/min-1 in the week with PA sessions (M = 1019.58, SD = 235.07) in comparison with the week days without PA sessions (M = 620.85, SD = 164.09, p = .03) and the weekend days (M = 545.82, SD = 162.24, p = .02). Finally, in Table 1 are the results about the time (minutes) spent in MVPA.

Table 1. Minutes spent in moderate to very vigorous physical activity (MVPA) in the three stages of assessment and significance level (p <.05).

Time spent per day (min)		**M**	**SD**
MVPA working days with PA sessions		84.17	26.80
MVPA working days without PA sessions		51.58	15.79
MVPA during the weekend		39.23	23.15
MVPA			***p***
Working days with PA sessions	Working days without PA sessions		.02*
	Weekend		.01*
Working days without PA sessions	Weekend		.26

M = Mean; SD = Standard Deviation

Conclusion and discussion

All participants performed an average of 150 minutes of MVPA per week, which follows the recommendation of the American College of Sports Medicine (2010) for adults. Furthermore, the MVPA in working days with PA sessions were significantly higher than those in the working days without PA sessions and during the weekend. Thus, this study highlighted the importance of structured PA programs to improve daily physical activity in people with schizophrenia.

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Effect of real-time visual feedback on mechanical efficiency and propulsion technique in novice able-bodied wheelchair users

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Abstract *Objective:* Handrim wheelchair propulsion is a cyclic bimanual skill that needs to be learned by any novice wheelchair-user in rehabilitation. The aim of this study was to evaluate the effects of learning wheelchair propulsion using real time visual feedback on the mechanical efficiency (ME) and selected wheelchair propulsion technique variables. *Methods:* 20 able-bodied subjects participated in this one-day study. A feedback group (FG; N=10) and a control group (CG; N=10) executed a similar dose of 80 minutes low-intensity steady-state wheelchair propulsion on a motor driven treadmill (0.18W/kg body weight). The FG received real-time visual feedback on different propulsion technique variables using data from the OptiPush measurement-wheel. During each of seven 2x4min practice trials one feedback variable was presented as a bar graph on a monitor in front of the subject. The following seven propulsion technique characteristics were presented in a counterbalanced order: braking moment, cadence, contact angle, peak force, push distance, smoothness and fraction of effective force. The CG received no feedback. The 12 minute pre- and posttests, without visual feedback, were used to evaluate differences between the FG and the CG in ME and propulsion technique *Results:*The push distance, cadence and contact angle of the pre and posttests showed an interaction effect, i.e. the FG increased more in these propulsion technique parameters compared to the CG. ME increased in the FG but no interaction effect of group*test was found. *Conclusion:* The current study shows that novice able-bodied participants are able to adapt to visual feedback on propulsion technique parameters. The FG improved their propulsion technique more, yet ME was not significantly more improved compared to the CG. Possibly, rehabilitation programs focused on wheelchair motor learning could incorporate visual feedback to further improve propulsion technique.

Effectiveness of a Wheelchair Skills Training Program for Community-Living Users of Manual Wheelchairs

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Abstract The aim of this study is to define the effect of manual wheelchair propulsion training, offered to wheelchair users after joining the community, on the ability of manual wheelchair propulsion. The subjects of the study were individuals who had no walking functions; and thus had to use wheelchair for mobility in daily life but without full capacity. The study started with obtaining a list of 95 people from the Prime Ministry Bolu Social Service Provincial Directorate. The number of the subjects was 24, who were categorized under training and control groups randomly. All of the participants in the training group, 14 people, completed the training program while the control group consisting of 10 people did not participate the training. In the statistical research, there was no meaningful difference between the training group and the control group in terms of sex, age and diagnosis. The participants were asked to fill out a questionnaire to get information about their functionality in daily life and socio-economic status. At the beginning of the study, their ability and safety when displaying these skills were evaluated with wheelchair training skill test. The same evaluation was carried out also at the end of the training. The training group attended a skill training session of 45 minutes three times a week for 4 weeks. The evaluations carried out after the training revealed that the success and safety rates in displaying the wheelchair propulsion skills by the individuals who participated the training had a meaningful increase statistically. In the research, it was observed in the training group that uneasiness in wheelchair activities decreased and individuals' ambition to work in a job increased. In line with the data obtained, it was concluded that the functionality of wheelchair users may be improved by the safe increase in the number of skills in daily wheelchair mobility and also the possibility of injury might be decreased. Based on this, it was understood that physiotherapists should include wheelchair skill training into their rehabilitation program.

Keywords: Wheelchair, Wheelchair User, Manual Wheelchair Propulsion Skills Training, Wheelchair Propulsion.

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Introduction

For people who are unable to walk, a wheelchair is one of the most important mobility aids. Wheelchair Skills Program for manual wheelchairs operated by their users is a standardized training (Wheelchair Skills Training) and evaluation method (Wheelchair Skills Test version 4.1) that permits a set of representative wheelchair skills to be onjectively, simply and inexpensively documented (www.wheelchairskills programme.ca, Best, Kirby et al, 2005; Kilkens, Post et al, 2003). The purpose of this study was to test the hypothesis that, in comparison with a control

group, the Wheelchair Skills Training Programwould improve the total percentage performance and safety scores on the Wheelchair Skills Test of community-living wheelchair users.

Methods

Participants

This was a randomized controlled trial. We enrolled 32 community-living manual wheelchair users, a sample of convenience. Participants were then randomly allocated to training (n=17) and control groups (n=15) by drawing lots.

Process

The pasticipants in the training group attend the Wheelchair Skills program version 4.1 (tanslated into Turkish) (www.wheelchairskills programme.ca) sessions, each 45 minutes long, 3 times a week for four weeks. Participants in the control group did not receive any placebo intervention. Each participant's training programme was organized separately, taking into account the skills that he or she had not successfully compledeted during the pretraining Wheelchair Skills Test version 4.1.

Statistics

Total percentage Wheelchair Skills Test scores were compared using the Mann-Whitney U test and covariance analysis. The variables appropriate for the covariance analysis are the performance and the safety percentage values. We compared the performance percentage values and the safety percentage values between the two groups by keeping the values before the training stable (as a covariant). The level of significance was set at $p< 0.05$ and two sided.

Results

The performance percentage after the training was found to be significantly higher in the training group (P=0.001) (Table 1). The safety percentage after the training was found to be significantly higher in the group taking the training (P=0.000) (Table 2).

Table 1. Comparison of pre- and post-test performance scores (%) between training and control groups. R^2= ,685 (Adjusted R^2 = ,655)* p<.05

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Performance (%)	1072,42	1	1072,423	15,850	,001*
Group	1128,46	1	1128,470	16,678	,001*
Error	1420,88	21	67,661		
Total	141386,7	24			

Table 2. Comparison of pre- and post-test safety scores (%) between training and control groups. R^2 = ,862 (Adjusted R^2= ,849) *p<.05

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Safety (%)	2099,78	1	2099,79	37,91	,000*
Group	3856,52	1	3856,53	69,63	,000*
Error	1163,04	21	55,38		
Total	118476,6	24			

Conclusion and discussion

Community living wheelchair users who received wheelchair skills training increased their total performance and safety scores.Training programmes hosted within the community will reduce training costs and alloe more people to attend training sessions.

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Wheelchair-specific fitness of inactive people with chronic spinal cord injury

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Abstract *Objectives:* To evaluate wheelchair-specific fitness of inactive people with chronic spinal cord injury (SCI) and to study associations among wheelchair-specific fitness components in this population. *Design:* Cross-sectional study. *Participants:* Physically inactive wheelchair users with chronic paraplegia (n=20, 15 men) or tetraplegia (n=9, 2 men). *Methods:* Participants performed three exercise tests in their own wheelchair to determine 1) highest 5s-power output over 15m-overground sprinting (P5-15m), 2) highest 3s-isometric push-force (Fiso); and 3) peak power output (POpeak) and peak oxygen uptake (VO2peak) over a peak test. *Results:* For the total group, mean±SD of POpeak was 39.3±22.9W, VO2peak 1.25±0.51 $L \cdot min^{-1}$, P5-15m 17.5±10.1W and Fiso 444±249N. Outcomes were significantly higher in the subgroup with paraplegia vs. tetraplegia (about 2 times higher, p<0.05). Correlations among outcomes were all significant (p<0.05) but weak to moderate for POpeak or VO2peak and P5-15m (r=0.69-0.79), POpeak or VO2peak and Fiso (r=0.50-0.64) as well as P5-15m and Fiso (r=0.55). *Conclusions:* Group results indicate 1) variable and low wheelchair-specific fitness levels compared to the general SCI population; and 2) weak to moderate associations among fitness components. All wheelchair-specific fitness components require continued attention after inpatient rehabilitation to prevent and improve low wheelchair-specific fitness of inactive people with chronic SCI.

Keywords paraplegia, physical fitness, tetraplegia, wheelchairs

Introduction

Maintaining fitness is important for people with spinal cord injury (SCI), as their fitness has a negative association with performance of activities of daily living (ADL), participation and quality of life. Relatively little is known about wheelchair-specific fitness of inactive people with chronic (longstanding) SCI. They are assumed to specifically suffer from low fitness given their relatively

inactive lifestyle, but also given their higher incidence of secondary health complications that may seriously impair fitness (upper-body pain, for example). The aims of this study were 1) to evaluate wheelchair-specific fitness of a group inactive people with chronic SCI, and 2) to study associations among wheelchair-specific fitness components in this group.

Methods

Participants were physically inactive wheelchair users with chronic spinal cord injury (age: 53±10y; body mass: 89 ±18; BMI: 28±5; TSI: 20 ±8; PASIPD-score: 11.1 ±10.1; sport participation: 0.1 ±0.4 h/week). In a standardized procedure taking place in the rehabilitation centers (van der Scheer et al. 2012), participants used their own wheelchair to perform three exercise tests. Outcomes determined were the highest 5s-power output over 15m-overground sprinting (P5-15m), the highest 3s-isometric push-force (Fiso) and peak power output (POpeak) and peak oxygen uptake (VO2peak) over a peak test (van der Scheer et al. 2012, van der Scheer et al. 2014). Descriptives for all outcomes were determined over the total as well as the subgroups with paraplegia and tetraplegia. Outcomes of the group with paraplegia vs. tetraplegia were compared with Mann-Whitney U-tests (p<0.05). Over the total group, Pearson's r was calculated among outcomes (p<0.05).

Results

Table 1 and figure 1 show descriptives and individual data of the outcomes. All fitness outcomes were significantly higher in the subgroup with paraplegia vs. tetraplegia (about 2 times higher; figure 1). Over the total group as well as the subgroups, levels were highly variable. Correlations among outcomes were all significant (table 2). Correlations among outcomes the three tests were moderate for POpeak and P5-15m, and were weak for POpeak and Fiso (r=0.64, figure 4), VO2peak and P5-15m (r=0.67), VO2peak and Fiso (r=0.50) as well as P5-15m and Fiso (r=0.55).

Conclusion and discussion

It seems that inactive people with chronic SCI are a group from the SCI population with variable and low levels in all wheelchair-specific fitness components (Dallmeijer et al. 1997, van der Woude et al. 1997, Hutzler 1998, Janssen et al. 2002, Haisma et al. 2006, Shiba et al. 2010, van Koppenhagen et al. 2013). The group may therefore specifically suffer even more from the negative consequences of low fitness. Research is needed to prevent low fitness of inactive people with chronic SCI, for example by monitoring of wheelchair-specific fitness in rehabilitation centers using standardized wheelchair tests, as well as to develop effective exercise interventions for improving fitness in this population without worsening overuse problems such as upper-body pain (van der Scheer et al. 2012).

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*ALLRISC-members: Ferry Woldring, Linda Valent (PhD), Heliomare, Rehabilitation Center, Wijk aan Zee, the Netherlands, Hans Slootman (MD) and Willemijn Faber (MD).

Table 1. Wheelchair-specific fitness outcomes of the group of inactive people with chronic spinal cord injury

	Total		**Paraplegia**		**Tetraplegia**	
	Mean ±SD	*N*	Mdn (25-75th)	*n*	Mdn (25-75th)	*n*
Peak aerobic work capacity						
POpeak (W)	39.3 ±22.9	28	51.2 (36.3-59.0)	19	18.7 (8.3-33.1)	9
VO2peak (L·min^{-1})	1.25 ±0.51	28	1.52 (1.07-1.75)	20	0.68 (0.54-1.07)	8
Anaerobic work capacity						
P5-15m (W)[1]	17.5 ±10.1	23	18.3 (14.5-26.4)	17	8.0 (4.8-15.5)	6
Isometric strength						
Fiso (N)[2]	444 ±249	28	525 (334-677)	19	211 (128-375)	9

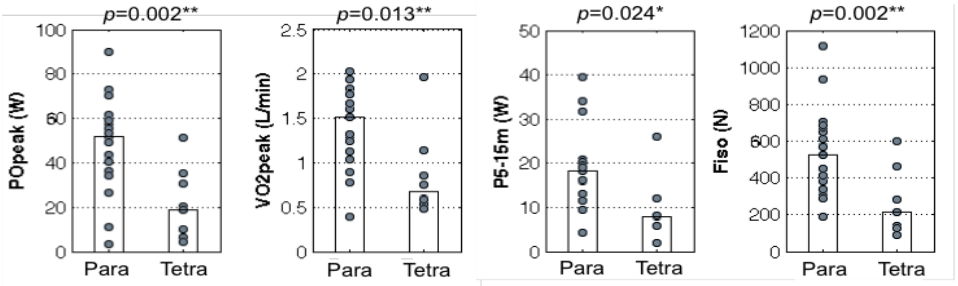

Figure 1. Wheelchair-specific fitness outcomes of group with paraplegia vs. tetraplegia, compared with Mann-Whitney U-tests (p<0.05). Bars represent group medians. Dots represent individual data.

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Reliability of inertial sensors for measuring wheelchair kinematics

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Abstract The reliability of inertial measurement unit (IMU) outcomes for measuring wheelchair kinematics was assessed. Twenty participants performed a course reflecting all different kinematic aspects of wheelchair basketball. During the test wheelchair kinematics were measured using a 24 camera 3D motion analysis system (Optitrack) as gold standard and three IMU's on wheels and frame. Results show good estimates for frame displacement and speed as long as no wheel skidding is involved. Frame rotation in the horizontal plane is best measured using the frame IMU gyro signal. Future algorithm development on this dataset will focus on improving displacement estimates in skidding conditions. The proved reliability of the IMU method, enables prospective research into the validity during real game conditions.

Keywords Wheelchair basketball; Inertial Measurement Units (IMU); Wheelchair kinematics;

Introduction

The purpose of this study is to develop a method to obtain reliable and valid outcomes of an inertial measurement unit instrumented wheelchair during a lab based wheelchair agility test. This study is part of a project aiming to further improve sports performance, especially in wheelchair basketball. Essential in wheeled sports performance is knowledge about individual athlete capacity, game demands (e.g. field position) and wheelchair kinematics (B. S. Mason et al., 2013). To determine wheelchair kinematics in an easy manner, small inertial sensors were mounted to the wheelchair, providing key outcome parameters. In a lab setting test these outcomes were checked for future ambulatory use, against an optical system that served as a gold standard.

Methods

Three inertial sensors (x-IMU; x-io Technologies; measuring linear acceleration, angular velocity and magnetic field orientation) were mounted on a basketball wheelchair (1 in the middle of the frame near the rear axis and 1 on each wheel axis). Infrared light emitting markers on the frame and wheels were recorded with a 24 camera 3D motion capture system (Optitrack, Natural Point)

for comparison. Athletes performed an agility test consisting of several tests closely reflecting the different aspects of wheelchair basketball (S. de Groot & Wheeler, 2003; Pansiot et al., 2011). The test consisted of: sprint (5m); straight normal (5m); straight fast with wheels skidding at stop (5m); slalom; slalom fast; figure eight; figure eight fast; U-turn normal; U-turn skidding inside wheel; turn on the spot; turn on the spot fast; pivot; star-twist (only bi-directional rotation); star-move (bi-directional rotation combined with moving back and forth).

The agility test was performed by 9 wheelchair athletes and 11 able bodied subjects.

The following kinematic outcomes of the IMU's and 3D motion capture system were calculated and compared for the wheelchair frame: linear displacement and velocity; horizontal rotation and rotational velocity

Frame displacement based on wheel IMU signals was calculated using two different algorithms: the arc tangents of two perpendicular acceleration vectors (WhA) and a complementary filter method using the low pass filtered acceleration signal and high pass filtered integrated gyro signal (WhAG). Frame rotation was calculated using the difference in left-right wheel displacement (WhAG) and using the frame IMU integrated gyro signal (FrG).

Results

The differences between the IMU outcomes and the gold standard (Optitrack) are expressed in absolute and percentage difference, as well as in Root Mean Square Error (RMSE). To determine overall differences per test part, all displacements (forward and backward) were summed. Wheel IMU's provide accurate displacement estimates for both algorithms and in most test conditions (Table 1, difference <2.5%). RMSE values vary from 0.04m during a straight track at normal speed up to 0.27m in highly dynamic (rotational) tests, such as the "star move". For speed the WhAG algorithm provides better results (lower RMSE values) compared to the WhA.

Table 1. Frame displacement and speed; Optitrack vs. IMU.
Average (n=20) displacement of relevant test parts. Difference between Optitrack (Opti) and two IMU algorithms (Wheel Acc. and Gyro: WhAG; Wheel Acc.: WhA), expressed in absolute difference, %, RMSE and speed RMSE. Best % results (<2.5 %) marked bold and poorest results (> 5%) marked italic.

Displacement	Displacement (m)			Difference (m)		Difference (%)		Displ. RMSE		Speed RMSE	
	Opti	WhAG	WhA	WhAG	WhA	WhAG	WhA	WhAG	WhA	WhAG	WhA
Straight 5m sprint	4.99	5.01	5.11	-0.02	-0.12	**1.5%**	3.0%	0.06	0.08	0.34	0.54
Straight 5 m slow	5.07	5.11	5.18	-0.04	-0.11	**1.1%**	**2.4%**	0.04	0.06	0.09	0.16
Straight 5m skid	4.96	4.66	4.67	0.30	0.30	*6.6%*	*6.9%*	0.17	0.17	0.58	0.64
Slalom	10.85	10.96	11.02	-0.12	-0.18	**1.1%**	**1.6%**	0.07	0.08	0.05	0.15
Slalom fast	10.54	10.26	10.38	0.28	0.16	3.0%	**2.3%**	0.18	0.18	0.21	0.30
Figure 8	10.32	10.39	10.46	-0.07	-0.14	**0.7%**	**1.4%**	0.04	0.05	0.05	0.15
Figure 8 fast	10.15	10.02	10.12	0.13	0.03	**1.7%**	**1.6%**	0.10	0.11	0.17	0.32
U turn L/R	6.95	6.99	7.05	-0.04	-0.10	**1.0%**	**1.7%**	0.04	0.06	0.07	0.16
U turn fast L/R	6.82	6.55	6.64	0.27	0.18	3.9%	3.1%	0.20	0.20	0.30	0.40
Turn L/R	0.47	0.47	0.55	0.00	-0.09	*displacement*		0.03	0.04	0.03	0.08
Turn fast L/R	0.67	0.67	0.82	0.00	-0.15	*close to 0 m*		0.04	0.05	0.10	0.18
Pivot L/R	2.58	2.61	2.68	-0.02	-0.10	**2.2%**	3.9%	0.04	0.05	0.05	0.12
Star twist	1.19	1.16	1.61	0.04	-0.42	*close to 0 m*		0.04	0.05	0.07	0.11
Star move	6.27	5.98	8.07	0.29	-1.80	*6.0%*	*31.7%*	0.27	0.27	0.16	0.25

For rotation (Table 2), all left and right rotations were summed to overall rotation during a test. The frame gyro (FrG) provides accurate rotational data (<2.5%) in all tests, whereas the rotation based on wheel displacement shows less accuracy in fast test parts. The RMSE values for both rotation and rotation velocity show similar results, with good results (low RMSE values) for the FrG and increasing RMSE values for WhAG based rotation in fast turning tests.

Table 2. Frame rotation and rotational velocity in the horizontal plane Optitrack vs. IMU.
Average (n=20) rotation of relevant test parts. Difference between Optitrack (Opti) and two IMU algorithms (Wheel Acc. and Gyro: WhAG; Frame Gyro.: FrG), expressed in absolute difference, %, RMSE and rotation velocity RMSE. Best % results (<2.5 %) marked bold and poorest results (> 5%) marked italic.

Rotation	Rotation (°)			Diff. (°)		Difference (%)		Rot. (°) RMSE		Rot. Vel.(°/s) RMSE	
	Opti	WhAG	FrG	WhAG	FrG	WhAG	FrG	WhAG	FrG	WhAG	FrG
Slalom	797.3	794.1	806.6	3.2	-9.3	**1.0%**	**1.3%**	2.71	3.11	8.98	4.83
Slalom fast	762.9	788.5	771.9	-25.6	-9.0	4.1%	**1.4%**	17.38	3.03	30.46	6.55
Figure 8	598.8	601.6	605.9	-2.8	-7.1	**0.8%**	**1.3%**	2.31	1.47	7.72	4.48
Figure 8 fast	588.0	622.9	594.9	-35.0	-6.9	*6.1%*	**1.3%**	10.75	1.57	23.16	6.23
U turn L/R	210.8	216.6	211.6	-5.7	-0.8	3.3%	**0.7%**	3.56	1.69	8.01	3.51
U turn fast L/R	211.5	267.5	213.0	-55.9	-1.5	*26.8%*	**0.9%**	31.32	1.74	34.58	4.99
Turn L/R	366.1	369.5	370.8	-3.4	-4.7	**1.3%**	**1.4%**	3.87	2.62	10.32	5.25
Turn fast L/R	371.8	377.2	376.6	-5.4	-4.8	**2.2%**	**1.4%**	7.63	3.15	25.65	8.47
Pivot L/R	366.2	369.0	370.9	-2.8	-4.7	**1.0%**	**1.4%**	2.44	2.66	8.91	5.26
Star twist	642.2	557.4	650.2	84.8	-8.0	*13.3%*	**1.4%**	8.44	1.74	26.70	7.00
Star move	610.0	636.6	615.6	-26.6	-5.6	4.6%	**1.2%**	16.27	1.37	17.83	4.62

Conclusion and discussion

IMU's in the wheelchair wheels provide good (Table 1) displacement estimates in most conditions, except when skidding (e.g. fast performance, sudden stop and star twist). Since skidding only occurs during short periods, the effect of these errors on the total estimated displacement is limited. For speed analysis the addition of the wheel gyro signal substantially improves the accuracy as expressed in the speed RMSE (Table 1, column 10&11).

The horizontal rotation calculation based on wheel displacement shows a similar pattern. The WhAG algorithm performs well (Table 2) as long as no skidding wheels are involved, otherwise differences increase (e.g. U turn fast, star twist). For all conditions excellent rotation estimates (Table 2) are achieved using the frame IMU gyro signal, so the use of this frame IMU is of substantial additional value. The small systematic overestimation indicates that results could even be improved by recalibrating the sensors, instead of using the factory calibration.

The IMU sensors in the chosen configuration provide reliable data for wheelchair kinematics. A simpler configuration with only one frame sensor, would also allow displacement estimation. However the considerable integration drift makes this option of limited practical use. In the combined configuration (wheels and frame IMU), forward frame acceleration can be used to detect skidding wheels. Future algorithm development on this data set will focus on combined analysis, correcting displacement estimates in skidding conditions. The proved reliability of the IMU method, enables prospective research into the validity during real game conditions.

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Cardiovascular disease risk in adults with spastic bilateral cerebral palsy

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Abstract This study was undertaken to assess biological and life-style related cardiovascular disease (CVD) risk factors and the 10-year risk of a fatal cardiovascular event in adults with spastic bilateral cerebral palsy (CP). Furthermore, we explored relationships between the 10-year risk and body fat, aerobic fitness and daily physical activity. Forty-three adults with spastic bilateral CP without severe cognitive impairment (mean age 36.6 ± 6 years; 27 men) participated in this cross-sectional study. Participants were recruited from ten rehabilitation centers in The Netherlands and via the patient association BOSK. Biological risk factors (blood pressure, blood lipids and lipoproteins, waist circumference and Body Mass Index [BMI] as indicators of body fat, aerobic fitness [VO2peak, cycle ergometry]) and lifestyle-related risk factors (daily physical activity level [accelerometry] and cigarette smoking) were assessed. A total 10-year risk of a first fatal cardiovascular event was estimated according to the European Systematic Coronary Risk Evaluation (SCORE risk). Relationships were studied using multivariable linear regression analysis.The following single risk factors were present: hypertension (n=12), elevated total cholesterol (n=3), low HDL-C (n=5; all men), high-risk waist circumference (n=11), obesity (BMI; n=5; all men), reduced aerobic fitness (on average 80% of reference values), reduced level of daily physical activity (on average 78% of reference values) and smoking (n=9). All participants had a 10-year risk ≤ 1 %. Corrected for gender, participants with higher waist circumference (β=0.28; p=0.06) or BMI (β=0.25; p=0.08) tended to have a higher 10-year risk. In this relatively young adult sample of spastic bilateral CP several single CVD risk factors were present. The 10-year fatal CVD risk was low and higher body fat tended to be related to higher 10-year risk.

Keywords Cerebral Palsy, SCORE, blood pressure, lipid profile, waist circumference, aerobic fitness

Introduction

Numerous studies of the general population have demonstrated that high body fat, low aerobic fitness and lack of physical activity are risk factors for cardiovascular disease (CVD). Persons with chronic physical conditions such as cerebral palsy (CP), may be at increased risk of developing CVD because they have low levels of both aerobic fitness and daily physical activity. Little is known about CVD risk in CP (Peterson, Haapala et al. 2012).

The aims of the present study were to investigate biological and lifestyle-related CVD risk factors, and to assess the clustered 10-year risk of a fatal cardiovascular event in adults with spastic bilateral CP, aged 25 to 45 years, without severe cognitive impairment. Furthermore, as body fat, aerobic fitness and daily physical activity are modifiable factors from an exercise perspective, we

explored associations between the 10-year risk and these factors. Because it is important to explore cardiovascular risk and begin preventive strategies early in life, a relatively young adult sample was studied.

Methods

Forty-three adults with spastic bilateral CP without severe cognitive impairment (mean age 36.6 ± 6 years; 27 men) participated in this cross-sectional study. Participants were recruited from ten rehabilitation centers in The Netherlands and via the patient association BOSK. Biological risk factors (blood pressure, blood lipids and lipoproteins, waist circumference and Body Mass Index [BMI] as indicators of body fat, aerobic fitness [VO_2peak, cycle ergometry]) and lifestyle-related risk factors (daily physical activity level [accelerometry] and cigarette smoking) were assessed (Van der Slot, Roebroeck et al. 2013). A total 10-year risk of a first fatal cardiovascular event was estimated according to the European Systematic Coronary Risk Evaluation (SCORE risk) (De Backer, Ambrosioni et al. 2003). Relationships were studied using multivariable linear regression analysis. All participants had a 10-year risk ≤ 1 % (see Table 1). Corrected for gender, participants with higher waist circumference (β=0.28; p=0.06) or BMI (β=0.25; p=0.08) tended to have a higher 10-year risk.

Results

The following single risk factors were present: hypertension (*n*=12), elevated total cholesterol (*n*=3), low HDL-C (*n*=5; all men), high-risk waist circumference (*n*=11), obesity (BMI; *n*=5; all men), reduced aerobic fitness (on average 80% of reference values), reduced level of daily physical activity (on average 78% of reference values) and smoking (n=9).

Table 1. Biologic and lifestyle-related risk factors of cardiovascular disease and 10-year fatal cardiovascular disease risk in adults with spastic bilateral cerebral palsy and Dutch reference samples

	Adults with CP (*n*=43)		Men versus Women with CP	Reference sample (*n*=[a])	
	Men (*n*=27)	Women (*n*=16)	*p*-value	Men (*n*=[a])	Women (*n*=[a])
Biological Risk Factors					
Blood pressure					
Systolic (mmHg) [mean (SD)]	126 (10)	126 (10)	0.98	122	113
Diastolic (mmHg) [mean (SD)]	86 (11)	81 (6)	0.03	77	73
Hypertension Systolic ≥140 Diastolic ≥90 mmHg [n (%)]	8 (30%)	3 (19%)	0.50	15%	8%
Blood lipid and lipoproteins [mean (SD)]					
Total cholesterol (mmol/L)	4.7 (0.8)	5.0 (0.9)	0.18	5.0	4.9
High-density lipoprotein (mmol/L)	1.3 (0.4)	1.8 (0.5)	<0.01	1.2	1.5
Total cholesterol/HDL ratio	3.8 (1.4)	2.9 (0.8)	0.005	4.6	3.5
Glucose (mmol/L) [mean (SD)]	4.1 (0.8)	4.7 (1.1)	0.06	5.2	5.0
Body fat [mean (SD)]					
Waist circumference (cm)	87.8 (16.2)	80.9 (9.9)	0.09	NA	NA
Body Mass Index (kg/m^2)	24.3 (6.0)	23.5 (3.0)	0.60	24.7	24
BMI ≥ 30 (%)	5 (18.5%)	0 (0%)	0.07	7.2%	8%
Aerobic fitness **(n=35)** [b]					
VO2peak (L/min) [mean (SD)]	2.4 (0.4)	1.7 (0.3)	<0.01	3.1 (0.14)	2.0 (0.14)

VO2peak as percentage of reference values [c] (%)	76.1 (11.5)	86.5 (12.8)	0.02		
Lifestyle-related risk factors					
Physical activity (min/day) [mean (SD)]	108.6 (49.3)	127.0 (59.4)	0.28	135.5 (46.1)[d]	175.0 (46.9)[d]
Physical activity as percentage of reference values (%)	81.9 (37.2)	72.6 (34.0)	0.42		
Current smoker (yes) [n (%)]	7 (26%)	2 (13%)	0.30	39%	39%
Smoking behavior (≥ 20cig/day)	1 (4%)	0 (0%)	0.44	36%	32%
Alcohol drinking never [n (%)]	11 (41%)	11 (69%)	0.08	9%	18%
Alcohol light drinking, 1 drink/day [n (%)]	12 (44%)	4 (25%)	0.20	35%	57%
Alcohol intermediate drinking, >1-<3 drinks/day [n (%)]	4 (15%)	1 (6%)	0.4	37%	21%
Alcohol heavy drinking ≥ 3 drinks/day [n (%)]	0 (0)	0 (0)	NA	19%	4%
Clustered 10-year fatal CVD risk					
SCORE risk (%) [mean (SD)]	0.19 (0.18)	0.06 (0.06)	0.001	NA	NA

[a] From a total of n=22.769 persons of the Dutch general population, subgroups (aged 20-49 years) according to the risk factor studied were selected (Blokstra A, Smit HA et al. 2005)
[b] Aerobic fitness was measured in 35 participant
[c] According to Shvartz (Shvartz, Rebold et al. 1990)
[d] Able-bodied age mates (*n*=45, age ± 5 years) measured with the same AM protocol (Van den Berg-Emons, Bussmann et al. 2010)
NA: not available; SD: standard deviation; BMI: body mass index; CVD: cardiovascular disease risk; SCORE: Systematic Coronary Risk Evaluation

Conclusion and discussion

In conclusion, in this sample of relatively young adults with spastic bilateral CP the 10-year fatal CVD risk was low, but several single CVD risk factors were present, of which (pre)hypertensive blood pressure was prominent. A higher level of body fat tended to be related to a higher 10-year risk, but no relations were demonstrated with aerobic fitness or daily physical activity. However, the studied sample was relatively small and other parameters (e.g. energy expenditure, sedentary time) or longer durations of measurement might deepen our understanding of daily physical activity and its potential association with CVD risk. Further research is warranted with other measures and/or a different sample (more severely affected persons, older ages) to get more insight in CVD risk and its relationships with modifiable factors. Thus far, the current findings highlight the importance of screening for CVD risk factors in spastic bilateral CP, specifically blood pressure and body fatness, and to start preventive strategies from young adulthood onwards.

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Age-related changes in foot shape and function in an adult population

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Abstract Foot problems may affect activities in daily living. Foot shape, foot pain and plantar sensitivity (foot function) are determinants for the risk of falling, specifically in elderly. Foot shape and function are influenced by age and the wearing of (ill-fitting) footwear. Feet of elderly are flatter and more pronated. Up to 82% of elderly wears ill-fitting footwear. The aim of this study was to determine age-related changes in foot shape and function in an adult population. Sixty-four participants were included, aged between 40-85 years. Foot shape was determined using tape measure and a 3D scanner. Foot function was determined using the Manchester Foot Pain Disability Index and a biothesiometer. Significant age-related changes were observed for foot shape and foot function. Feet of elderly were flatter and wider than feet of younger adults. Foot function decreased with age. These results can be useful for shoe manufacturers in developing correctly-fitting shoes for an adult population.

Keywords age-related, foot structure, foot function, adults, plantar sensitivity, footpain

Introduction

Foot problems may limit healthy adults, specifically elderly, in performing daily life activities[1]. Changes in foot shape, increased foot pain and decreased foot sensitivity, as measures of foot structure and function[2], are determinants for an increased risk of falling[3-5]. Important factors for changes in foot shape and function are age and the wearing of ill-fitting footwear[4,6,7]. Feet of older adults (mean age 80.2 years) are flatter and more pronated than feet of younger adults (mean age 20.9 years)[7]. Ten percent of young adults (20-35 years) experience footpain, compared to 52% of elderly (> 65 years)[6]. Up to 82% of the population aged >60 years wears ill-fitting footwear[4.] Wearing ill-fitting footwear might be a consequence of changes in foot shape and vice versa. Providing an overview of foot shape and foot function in an adult population might accommodate shoe manufacturers in developing correctly fitting shoes for adults.

Methods

Measurements took place at participants' homes or to them familiar public places. In total 64 male and female participants with and without footpain were age-stratified in four age-groups: 40-45, 50-55, 60-65 and 70-75 years. Exclusion criteria were 1) foot wounds, 2) footwear modification,

including individual insoles, 3) amputation of (a part of) the lower limb, 4) the self-reported inability to stand for five minutes without support and 5) being treated for footpain within 6 months prior to the measurements.

Foot shape was determined using a tape measure and a 3D scanner (Rodin4D, France) and included foot length, ball width, ball height, instep width, instep height, ball circumference, low instep circumference, high instep circumference and heel-instep circumference.

The prevalence of disabling footpain was assessed using nine items for Functional Limitation of the Manchester Foot Pain and Disability Index[8]. These items were translated into Dutch, but not validated. Participants could answer the items as 'never', 'sometimes', or 'often/always'. When one or more of the items were answered as 'often/always', participants were considered to have disabling footpain.

Foot sole sensitivity was determined using a biothesiometer (Vibrameter®, Somedic, Hörby, Sweden) on the regions of the hallux, MTP-1, MTP-5 and calcaneus. The average of the vibration perception threshold (VPT) and vibration disappearance threshold (VDT) was determined, called the vibration threshold[9]. Measurements were performed three times.

The effect of age on foot shape and foot sole sensitivity was determined using Ancova. Covariates were body length, body weight, BMI and gender. For data analysis values for vibration thresholds were log-transformed. A linear trend chi-squared test was performed for the effect of age on the prevalence of disabling footpain.

Results

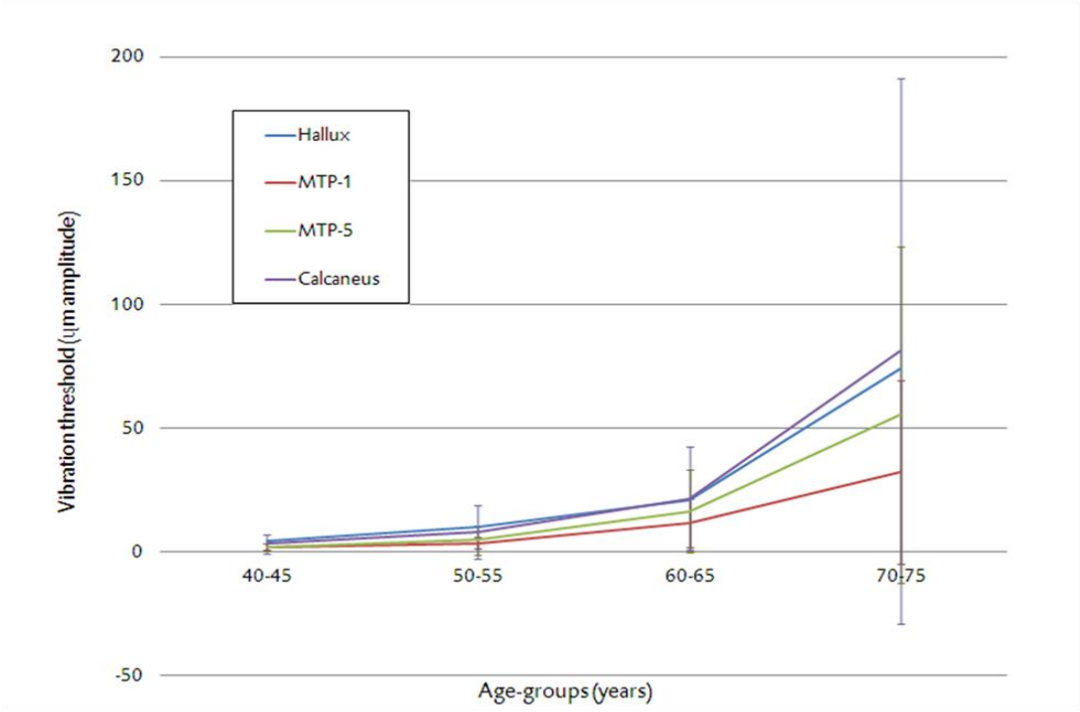

Figure 1. Vibration threshold of the right foot according to age

Significant age-related changes in left and right foot were observed for foot length, ball width, ball height, instep width, instep height and high-instep circumference ($P<0.05$). Foot length increased with age, whereas ball height and instep height decreased with age. Instep width and high instep circumference increased from the age of 50 years. At 40 years these measures were similar to the age of 60 years.

When log-transformed and corrected for body length, weight, BMI and gender, the vibration threshold increased exponentially with age at all four sites of the foot sole ($p<0.01$) (Figure 1).

In total, 23.4% of the participants experienced disabling footpain. A non-significant positive linear trend was observed for the prevalence of footpain with age ($p=0.116$).

Conclusion

This study is the first to provide insight in age-related changes of foot shape and function over a broader range of age-groups, including the middle aged population. All foot shape measures changed with age, with the exception of ball circumference, low instep circumference and heel-instep circumference. Feet of elderly were flatter and wider than the feet of younger adults. Foot function deteriorated with age. Sensitivity of the foot sole decreased, while a trend was found in which elderly experienced more footpain than younger adults. These results suggest that shoe manufacturers should take age-related factors into account when developing footwear for an adult population.

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Initial steps towards an evidence-based classification system for golfers with physical impairments

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Abstract *Introduction:* The present overview is a first step towards an evidence-based classification (EBC) system according to International Paralympic Committee (IPC) regulations in handigolf and aims to develop a conceptual framework of classification and proposes future research steps towards an EBC system. *Method:* Pubmed was used to select and review relevant scientific papers on three main themes: 1) Classification in Paralympic sports 2) Performance determining factors in golf, 3) Impact of impairments on golf performance. IPC-regulations concerning classification were gathered on the IPC website and in international literature. *Results:* There are two challenges in developing an EBC system as required by the IPC. The first is defining activity limitation caused by impairment solely and not influenced by training, talent or motivation. The second is the width of the sport classes, which must be a balance between maximizing the number of competitors and minimizing the variability of activity limitation within a class. Literature on performance determining factors in golf showed that timing, accuracy and control, work per joint, range of motion, balance and flexibility are important performance determining factors. The few articles found on the impact of impairments on golf performance were associated with limb deficiencies and addressed the issues of the asymmetric golf movement and the possible beneficial effect of prosthetic use. Based on this first analysis a conceptual framework was developed. *Conclusion:* Developing an EBC system is challenging, because activity limitation caused by impairment and the width of sport classes are hard to define scientifically. Researches should first understand the activity by use of performance determining factors. Then use the proposed conceptual framework to distinguish activity limitation caused by the impairment from performance and finally define eligibility criteria and sport classes.

Keywords Classification system, Paralympics, golf performance, Activity limitation

Introduction

Though handigolf is a very popular sport, it is, at this moment, not part of the 23 summer sports that are included in the Paralympics. One of the reasons is the absence of a classification system that classifies impairments. With the approval of the IPC Classification Code in 2007, the International Paralympic Committee (IPC) requires all Paralympic sports to have an evidence-based classification (EBC) system, in which understanding the activity limitation caused by impairment is one of the main tenants.

The present review can be considered as an exploratory review to reveal the present knowledge and the possible problems associated with developing an EBC system. The final goal is to develop a conceptual framework for classification and propose future research steps towards the development of an EBC system in handigolf. This could also facilitate and underpin future innovative research on EBC systems for other Paralympic sports. In this research, two steps will be taken: 1) define performance determining factors in able-bodied golf and 2) examine rehabilitation literature on the impact of physical impairments on the golf performance.

Methods

Pubmed was used to find relevant articles for the three main themes; Classification in Paralympic sports, performance determining factors in golf and the impact of physical impairments on golf performance. The following key words were used to find literature in the three main themes:

Classification in Paralympic sports: 'Classification & sport' in combination with 'Paralympic', 'amputation' and 'wheelchair' separately. The IPC website was searched for relevant information concerning their classification policy.

Performance determining factors in able-bodied golf: 'golf' and 'golf' in combination with 'athletic performance', 'biomechanics', 'task performance and analysis', 'golf swing', 'balance' and 'swing technique' in various combinations was searched for. Only the articles focusing on (part of) the golf movement were used for the exploratory review.

Impact of impairments on golf performance: 'golf' in combination with 'impairment', 'disabled people', 'disability evaluation', 'wheelchair' and 'amputation' separately.

Results

EBC is based on two cornerstones: 1) the eligibility criteria in terms of type and severity of impairment and 2) the methods for classifying eligible impairments according to the extent of activity limitation they cause (Tweedy, Vanlandewijck 2007). Activity limitation caused by the impairment has to be distinguished from activity limitations caused by other factors like training, talent and motivation (World Health Organization, 2001). A final challenge is defining the number and width of the sport classes, which must be a balance between maximizing the number of competitors and minimizing the variability of activity limitation within a class. At this moment, only five out of 28 Paralympic sports have started to support or improve their classification system with evidence that has been published in literature.

The exploratory literature search showed that timing, accuracy, control, work per joint, range of motion, balance and flexibility are performance determining factors in able-bodied golf. Figure 1 illustrates how the performance determining factors can be used to distinguish activity limitation caused by impairment from regular performance in handigolf.

Relevant rehabilitation literature on the impact of impairments on golf performance is very scarce to date, and only focused on limb deficiencies. The literature highlighted the beneficial effect of prosthetic use and the issue of the asymmetric movement and therewith the importance of the side of the limb deficiency.

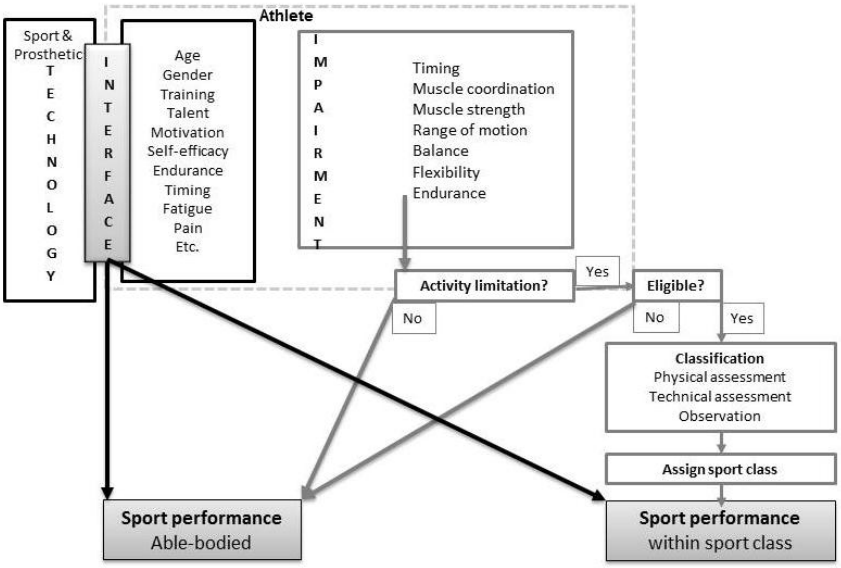

Figure 1. Conceptual model of classification and sport performance

Conclusion and discussion

Defining activity limitation and the width of sport classes scientifically is most challenging in developing an EBC system and only five Paralympic sports have started to support or improve their classification system scientifically. Performance determining factors in golf are found to be timing, accuracy, control, work per joint, range of motion, balance and flexibility. The few articles on the impact of impairment on golf performance were all based on limb deficiencies. Therefore, it is advised that the next step towards EBC is to define activity limitation caused by limb deficiencies, using figure 1. To finally define eligibility criteria and methods for classifying eligible limb deficiencies according to the extent of activity limitation they cause. Thereafter, steps can be repeated for other impairment types to complete the EBC system.

Acknowledgements

The authors would like to thank P. van Duijn for initiating this research project and A. Kruimer (†) and P. van Leeuwen for their enlightening view on classification systems in Paralympic sports.

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Mechanisms of autonomic regulation in subjects with Spinal Cord Injury

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Abstract Spinal Cord Injury (SCI) patients are known to suffer from autonomic failure as a result of their injury. By other side it is well established that autonomic activity plays an important role in social cognition and that impairments in the ability to interpret social information are commonly observed in a variety of mental disorders which also correlate with rigid autonomic activity. We propose that subjects diagnosed with spinal cord injury, that are found in paraplegic condition and presenting symptoms of adjustment disorder associated with experiencing a period of social and work reintegration from a disabling condition, sufer alterations in social cognition components that correlate with rigid autonomic activity. We measured the autonomic nervous system (ANS) function by heart rate variability (HRV). The Interbeat intervals were measured for 5 min via the Polar RS800CX heart rate monitoring system at 1000 Hz. HRV was mesured, as autonomic marker, in 18 healthy subjects and 10 subjects with SCI. A 5 min. quiet sitting period at the beginning of the assesment was used to collect baseline HRV. Than HRV was mesured during performance of the The Reading the Mind in the Eyes Test, this test assesses the emotional inference aspect of theory of mind, a component of social cognition. The results show that both groups have similar global performance in the test, however the group of healthy subjects presented better performance on more difficult trails. The group of healthy subjects show high HRV at baseline and during the test relative to the group of subjects with SCI. The group of healthy subjects showed significantly higher HRV during the task than at baseline. By other side, there is not difference in HRV in the subjects with SCI between baseline and the task. HRV component, that reflect vagal function, increse during performance of social cognition task in healthy subjects. This changes are not observed in subjects with SCI, which may reflect an inflexible autonomic activity in this group and possible adjustment problems in subjects with SCI after a rehabilitation process.

Keywords Spinal Cord Injury, Heart rate variability, Social cognition

Introduction

The perception, interpretation and generation of responses to the intention, dispositions and behaviors of others are known as social cognition (Green, 2008). The recognition of facial expressions and the ability to infer the likely mental states of other people are an important feature of social cognition, this ability is called Theory of Mind and may predict functional social capacity beyond more traditional neurocognitive assessments that index working memory, psychomotor speed, and attention (Bora, 2006). The emotions that humans experience while interacting with their environment are associated with varying degrees of physiological arousal (Bora, 2006). A key system involved in the generation of this physiological arousal is the autonomic nervous system (ANS). Heart rate variability (HRV) analysis is emerging as an objective measure of regulated emotional responding (generating emotional responses of appropriate timing and magnitude), and functions related to social cognition and Theory of mind.

The polyvagal theory and the Neurovisceral integration model proposes that the ANS, through vagal tone activity and activity of the prefrontal cortex improves the interactions of a subject with their envoirments through an inhibitory effect on the sino-atrial node (pacemarker) (Appelhans and Luecken, 2006), both theories presented above are similar in that they specify a critical role for parasympathetically mediated inhibition of autonomic arousal in emotional expression and regulation and maintain that HRV measures are informative about individuals' capacity for this aspect of regulated emotional responding and functions related to social cognition (Porges, 2003). There is evidence that at rest, subjects with spinal cord injury (SCI) have a predominance of sympathetic autonomic activity which correlates with low heart rate variability (Jan, 2013). Our hypothesis proposes that this type of basal activity of the ANS decrease autonomic flexibility that has been described as favorable for social cognition tasks.

Methods

Participants

In order to test our hypothesis, HRV was mesured, as autonomic marker, in 18 healthy subjects (10 male and 8 female) and 10 subjects with SCI (4 female and 6 male), diagnosed with paraplegia, who were pursuing a period of adaptation and socio-labor integration. A 5 min. quiet sitting period at the beginning of the assesment was used to collect baseline HRV. Than HRV was mesured during performance of the The Reading the Mind in the Eyes Test (RMET), which assesses the affective component of the theory of mind.

Task

RMET assesses the emotional inference aspect of theory of mind. This test Consist of 36 pictures of the eye region of a face. Participants are asked to choose which of four words best describes what the person in each photograph is thinking or feeling. At the end of response participants had noted the security level of their answers (1 unconvinced; 2 fairly convinced; 3 convinced).

Data analysis

Raw data was extracted as a text file and imported into Kubios (version 2.0, 2008, Biosignal Analysis And Medical Imaging Group, University of Kuopio, Finland, MATLAB). Kubios was then used to calculate HF HRV (0.15–0.4 Hz; normalized units), using the Fast Fourier transform, and the root mean square of successive RR intervals (RMSSD). The HF band of frequency domain and HRV RMSSD are influenced almost exclusively by parasympathetic activity and have been argued to be an index of vagal tone (Lane et al., 2009). A Wilcoxon non- parametric test was performed to analyze the results that were significantly different ($p<0.05$).

Results

Based on our results it was observed that the group of subjects with SCI had a worse performance in the test, a significantly lower level of security on responses compared with the group of healthy people (Fig 1), lower HRV at rest, and a smaller increase in the HRV during the task relative to the baseline condition (Fig 2.). These results show that both groups have similar performance in RMET(0.0693), however the group of healthy subjects respond with a higher level of security compared with the group of subjects with spinal cord injury ($p=0.0049$). Figure 2 show the mean of the root mean square of differences of successive RR intervals (RMSSD) at baseline and during the task in both groups. The group of healthy subjects show high HRV at baseline ($p=0.0039$) and during the RMET ($p=0.0007$) relative to the group of subjects with SCI.

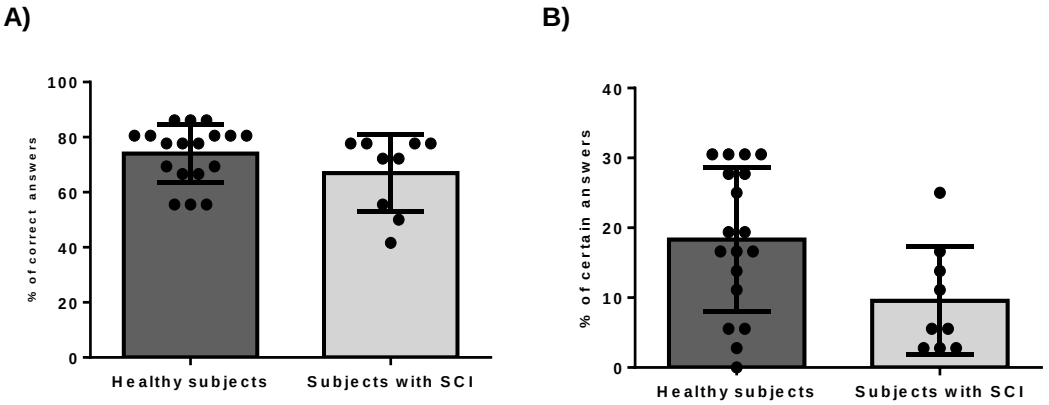

Figure 1. Percent of correct (a) and certain (b) answers in both groups.

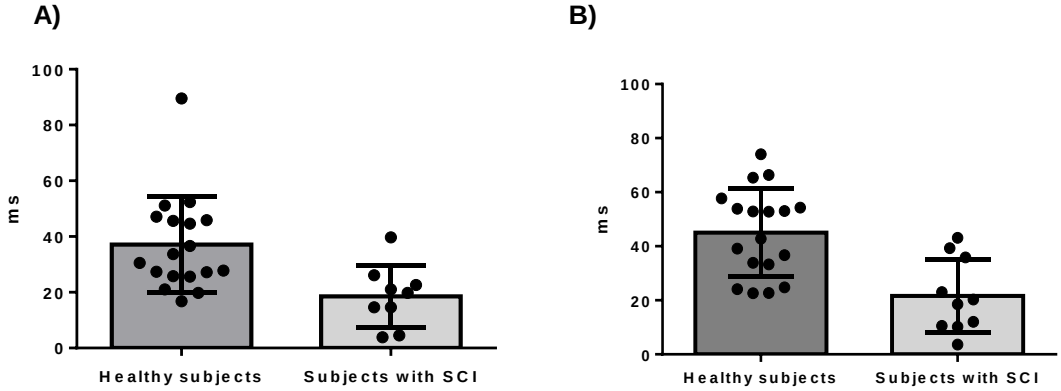

Figure 2. HRV power compared between both groups during baseline and during the task.

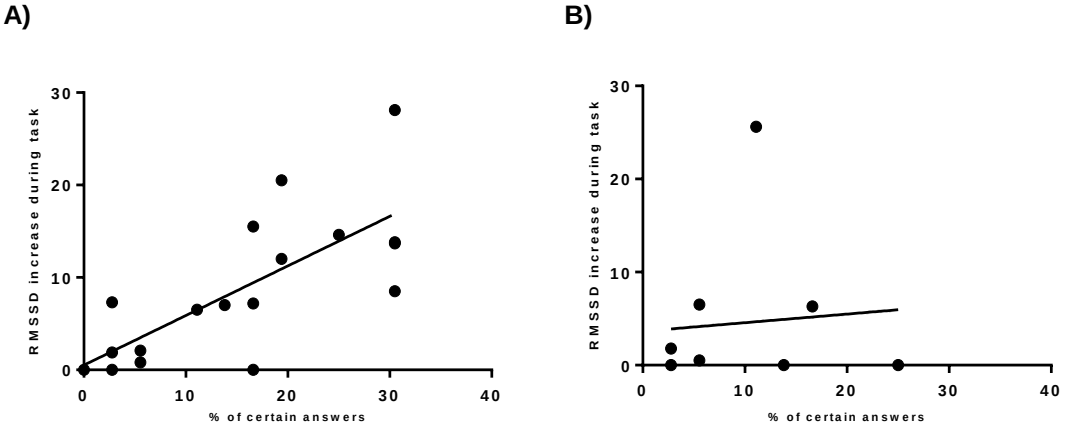

Figure 3. Correlation between increase in parasympathetic activity and safety responses in both groups.

In Healthy subjects (Figure 3 a) there is a strong correlation between increased HRV during the task relative to the baseline condition and percent of certain answers (r=0.735; p= 0.0005). This phenomenon doesn´t occur in the group of subjects with spinal cord injury (Figure 3b) (r=0.097; p=0.795).

Conclusion

These results suggest that there be alterations in social cognition in subjects with SCI, diagnosed with paraplegia, who were pursuing a period of adaptation and socio-labor integration. And also confirm a positive correlation between limitations in autonomic flexibility and worse performance in social cognition tasks.

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2-D geometric model of wheelchair adjustment

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Abstract Most settings of a standard manual wheelchair (MWC) alter its whole geometry in a way that generally cannot be predicted because MWC dimensions (i.e. lengths and angles) are measured in different reference frames. This issue has been addressed and solved using a 2-D geometric model, which equations have been implemented into an interactive Java simulation software primarily designed for MWC users, adjustment specialists, clinicians and scientists. The three wheelchair, chassis and terrestrial reference frames generally used for measuring MWC dimensions have been firstly defined and then used to write a set of intricate equations taking into account the interdependent relationships between settings of MWC elements (i.e. seat, backrest, legrest, footrest, rear and front wheels). This 2-D model allows to rebuild a given standard MWC from about 20 lengths that can be easily measured with a single measure-tape. No angles are included in the model inputs as they practically cannot be measured. The model outputs are the positions and orientations of all MWC elements in the relevant reference frames. Different settings and adjustments can thus be numerically tested and the results are given in terms of wheelbase, seat height or tilt angles, for instance. The 2-D geometric model developed in this study brings a solution to the tricky problem of the adjustment of a standard MWC as it allows to compute and predict the outcomes of any setting without spending time and energy for transferring the user out and into his MWC nor for loosening and clamping any bolt. This model has been implemented into an interactive Java simulation software that gives both numerical and graphical results of the chosen settings. This simulation software is currently available in four languages (French, English, Arabic, Chinese) but it can be greatly improved by integrating other types of MWC and other languages, and it should later evolve into 3-D.

Keywords Wheelchair, adjustment, model

Introduction

Given the numerous trademarks and the various models of manual wheelchairs (MWC), their geometry may vary a lot. International Standards (ISO 7176-7, 1998; ISO 7176-5, 2008) try to pass over these particular geometries by defining generic MWC dimensions that are measured according with specific processes but in different explicit or implicit reference frames. Some of these dimensions can easily and independently be measured as, for instance, front and rear wheels diameters, widths and lengths of the seat, backrest, and legrest. On the other hand, seat and backrest angles are measured with respect to the horizontal and vertical axes of a terrestrial reference frame, respectively, whereas angles between seat and backrest or seat and legrest are

relative values. Lastly, the vertical (Δy_O) and fore-aft (Δx_O) positions of rear wheels axle are defined with respect to the intersection of seat and backrest reference planes. According to their definitions, most of these dimensions and angles are not independent of each other, but the relationships between them as well as their relationships with MWC settings are unknown. So, these dimensions and angles cannot be predicted and should be measured each time a setting is changed. International Standards thus appear to be unuseful for adjusting a MWC or for comparing the settings of two different MWC.

The aim of this study was to find a solution to this tricky problem and to build a 2-D geometric model of a standard MWC based on dimensions that could easily be measured with a simple measuring tape. Indeed, in the current adjustment of a MWC, it seemed better to avoid direct measurement of angles, because it is sometimes impossible. Moreover, this model should allow to compute all the dimensions and angles defined in International Standards and also the variations of these dimensions and angles induced by setting changes. Finally, this model had to be implemented into an interactive Java simulation software primarily designed for MWC users, adjustment specialists, clinicians and scientists.

Methods

Apart from the absolute terrestrial reference frame, two other relative ones have been defined that are implicitly used in International Standards for measuring MWC dimensions and that are linked to the MWC and to its chassis, respectively. Wheelchair chassis was then decomposed in several triangles, which vertices are characteristic points of MWC elements (e.g. rear and front wheels axles, seat, backrest and legrest ends).

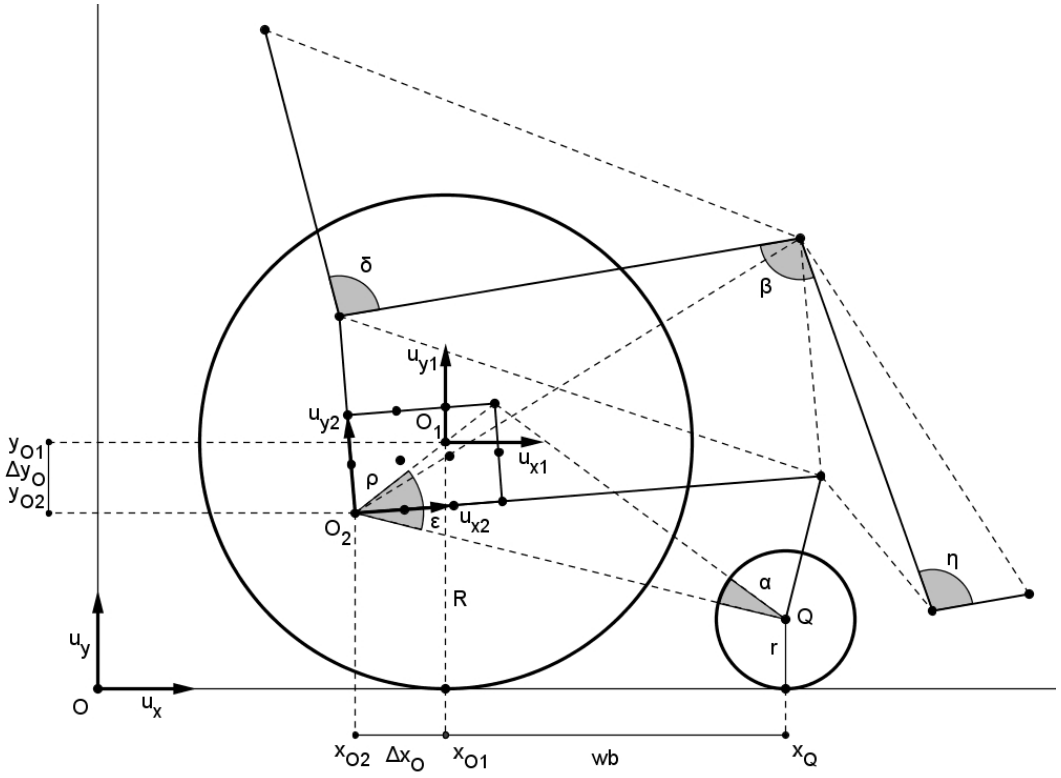

Figure 1. Reference frames and selected lengths and angles of the 2-D geometric model of a standard wheelchair.

The lengths of these actual or virtual triangles were used to compute some of their sides and angles in a precise order using Al Kashi's theorem. This set of intricate equations defines a 2-D geometric model of a standard MWC (Figure 1) that takes into account the interdependent relationships between MWC dimensions, angles and settings.

Results

Among the 27 angles and dimensions defined in ISO 7176-7 (1998), only 6 are used as inputs of the model: backrest height, seat and footrest lengths, handrim, rear and front wheels diameters. Twelve dimensions are not taken into account because either they are not included into a 2-D model (e.g. seat and backrest widths) or they relate to optional accessories (e.g. armrest and headrest). The nine remaining angles and dimensions are computed by the model that also need 14 other lengths as inputs (Fig.1: dashed lines). The model outputs are the dimensions, positions and orientations of all MWC elements in the reference frames used in ISO 7176-7 (1998), as well as a few others defined in ISO 7176-5 (2008) like wheelbase (wb), full and reduced overall MWC length or overall height, for instance.

The equations of the 2-D geometric model have been transcribed into a previous software written with Java (Vaslin et al. 2011) that allows a simplified display of the MWC and the user, the latter being only defined by his anthropometric dimensions (i.e. weight, height, segments lengths). With the help of sliders, the software instantaneously displays on a PC screen the consequences of most settings on MWC dimensions and angles, on user's seating posture and on the static stability of the {User+MWC} system. Different settings and adjustments can thus be numerically tested without spending time and energy for transferring the user out and into his MWC nor for loosening and clamping any bolt.

Conclusion and discussion

The 2-D geometric model developed in this study and implemented into an interactive Java simulation software brings a solution to the tricky problem of the adjustment of a standard MWC as it allows to compute and predict both numerical and graphical outcomes of several settings. It should thus be helpful to scientists, clinicians, adjustment specialists but also to MWC users.

The simulation software is currently available in four languages (French, English, Arabic, Chinese) but it can be greatly improved by integrating other languages (e.g. Dutch, Portugese, German) with the help of international specialists. Moreover, the 2-D geometric model still needs to be generalized, that is to evolve in 3-D and to integrate other types of MWC.

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Walking activity of children with cerebral palsy and children developing typically: a comparison between the Netherlands and the United States

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Abstract and figure 1 are part of the early online version of the publication that can be accessed via Disabil Rehabil, Early Online: 1–7. *© 2014 Informa UK Ltd.* *DOI: 10.3109/09638288.2014.892639.*

Abstract The purpose of this study was to compare walking activity of children with and without cerebral palsy (CP) between the Netherlands and the United States. A cross-sectional analysis on walking activity data from an international retrospective comparison study was performed, including a convenience sample of 134 walking children aged 7–12 years with spastic CP, classified as Gross Motor Function Classification System (GMFCS) level I (N=64), II (N=49) or III (N=21), and 223 typically developing children (TDC) from the Netherlands and the United States. Walking activity was assessed during a one-week period using a StepWatch™ activity monitor. Outcomes were the daily number of strides, daily time being inactive and spent at low (0–15 strides/min), moderate (16–30 strides/min) and high stride rate (31–60 strides/min). Walking activity was compared between countries using multiple linear regression analyses. It was found that walking activity of TDC was not significantly different between countries. Compared to their American counterparts, Dutch children in GMFCS level I and II showed less walking activity ($p<0.05$), whereas Dutch children in GMFCS level III showed more walking activity ($p<0.05$) (**Figure 1**). The absence of differences in walking activity between Dutch and American TDC, and the presence of differences in walking activity between Dutch and American children with CP suggest that between-country differences affect walking activity differently in children with CP.

Keywords Cerebral palsy, children, physical activity, environment

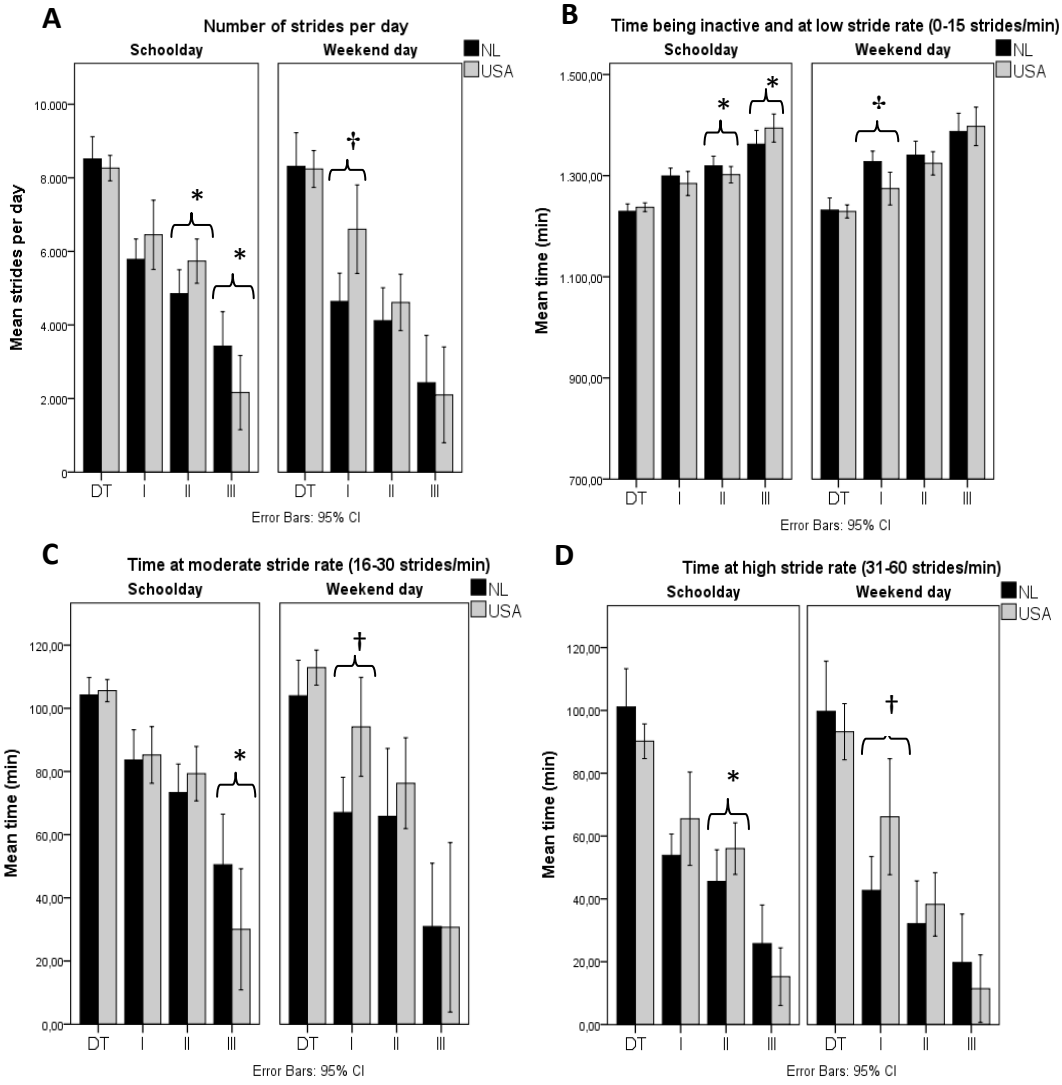

Figure 1. Means (95% CI) for walking activity on schooldays and weekend days among children developing typically, and children in GMFCS levels I-III. Means of children in each GMFCS level are compared between the Netherlands (NL) and the United States (USA): (A) Strides per day, (B) Time spent being inactive and at low stride rate (0-15 strides/minute), (C) Time spent at moderate stride rate (16-30 strides/minute), (D) Time spent at high stride rate (31-60 strides/minute); * $p<0.05$, and † $p<0.01$ represent significantly different walking activity between countries within each category. **Figure 7.** Mean (N=5) SVA [degrees] (A), sagittal knee angle [degrees] (B) and internal knee moment [$Nm \cdot kg^{-1}$] (C) for

Introduction to front crawl in students with autism spectrum disorder

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Abstract The aim was to assess the progress in front crawl fluctuation and displacement of students with Autistic Spectrum Disorder (ASD), in an adapted swimming program. This study included five students diagnosed with ASD. The program consisted of 15 sessions emphasizing the guidance in the water, fluctuations and front crawl displacement. The classes were filmed, and the students were evaluated in the following items: Displacement in the prone position with float; Initiation to front crawl with float; Front crawl (at least the legs) without float. For each item, it was assigned a value ranging from 0 = "Cannot do or refuses to do"; 1 = "Performs with driving physics"; 2 = "Performs with verbal instruction and demonstration"; or 3 = "Performs spontaneously after the group instruction". These values permitted to observe if they were doing the exercise, and also, the way they did it. Results indicate that, in the initial evaluation, the subjects were given the values 0 and 1, to the skills assessed, and meaning that they did not performed or refused to perform the exercises. At the end, all the assessed students were able to perform, at least, two of the three skills evaluated with physical assistance or a direct teacher instruction and prevailing the values 1 and 2. It also indicates that breaking the touch barrier appeared to influence the development of fluctuation and displacement, in the water, with confidence and autonomy. In conclusion, the participants demonstrated improvement in the assessed skills, showing positive results not only in the execution, but also in the predisposition to the proposed activities.

Keywords Autism spectrum disorder, Aquatic skills, Swimming, Water activities.

Introduction

The Autistic Spectrum Disorder (ASD) is a disorder of human development characterized by losses in three areas: a) difficulties in verbal and non-verbal communication, facial expressions, body language and rhythm; b) difficulty of relating, with the inability to share feelings and emotions; c) difficulty in the use of imagination, characterized by rigidity and inflexibility, and also, obsessive and ritualistic behaviors (American Psychiatric Association, 2000).

The benefits of regular physical activity are established. However, the participation in physical activities is usually a challenge for people with ASD in terms of lower levels of motor

development, low motivation, difficulty in planning and generalization, and also, the difficulty of self-monitoring activities (Todd & Reid, 2006).

This study aims to evaluate the effects of a program adapted for aquatic activity in the development of front crawl, in students with autistic spectrum disorder.

Methods

Participants

The study included five students diagnosed with ASD. The participants (4-Male and 1-Female) showed features commonly observed in people with ASD as a lack of formal verbal language, self-aggression, stereotyped movements, rituals and restricted interests.

Procedure

The intervention program consisted of 15 sessions divided into four months. Each session had 20 minutes, in a room, with activities on safety rules and expected behaviors; 10 minutes of stretching, 40 minutes of water activities and 10 minutes of relaxation. The classes were organized from the learning of safety rules in the aquatic environment, evolving into the development of basic skills for swimming, such as flotation, breath control and propulsion, emphasizing on the front crawl characteristics.

Evaluation

At every first class of the month, and during four classes, it was possible to film in order to consider the evaluation of the following items: displacement in the prone position with float; initiation to the front crawl with float; front crawl (at least the legs) without float. For each item, it was assigned a value ranging from 0= “Cannot do or refuses to do”; 1= “Performs with driving physics”; 2= “Performs with verbal instruction and demonstration”; or 3= “Performs spontaneously after the group instruction.” These values permitted to observe if they were doing an exercise, and also, the way they did it.

This research was approved by the Ethics Committee of the Federal University of Santa Catarina under the protocol 911/10.

Results

The graphs show the participants data (P1, P2, P3, P4 and P5) on the skills assessed in the four classes (C1, C2, C3 and C4) that were videotaped and considered for evaluation.

The results show that in the initial classes (C1 and C2), especially for more complex tasks presented in figures 2 and 3 respectively, the subjects showed prevalence of value zero ("Cannot do or refuses to do"). Nevertheless, at the end of the intervention, the participants began to perform tasks with physical conduction of teachers, and independently, after direct instruction (prevalence of value 1 and 2) as they are shown in figure 1 and 2.

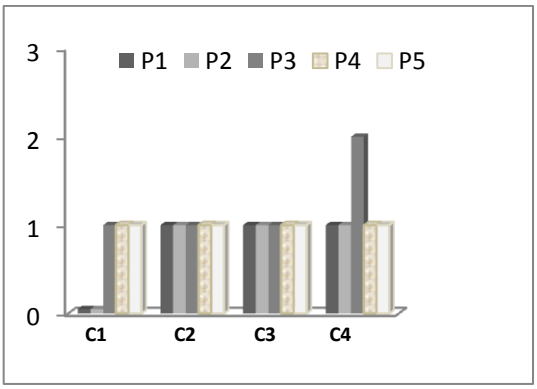

Figure 1. Displacement in the prone position with float

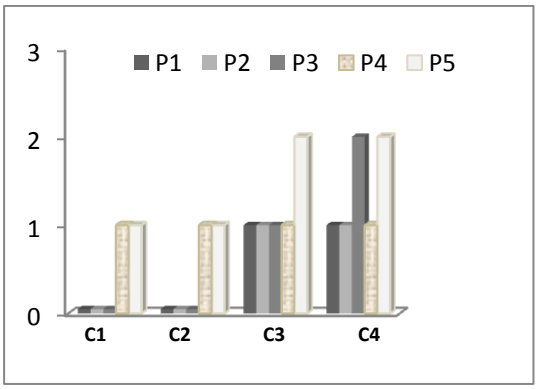

Figure 2. Front crawl with float

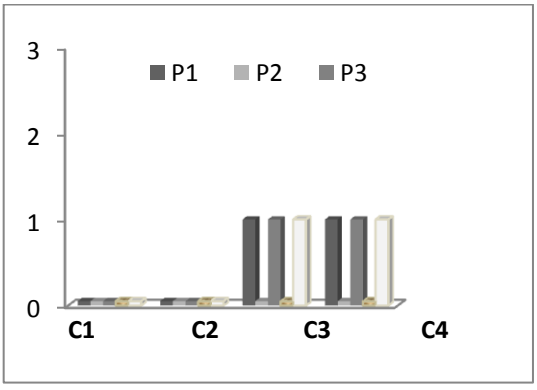

Figure 3. Front crawl (at least the legs) without float

Conclusion and discussion

In general, the intervention data suggest a positive trend, in the three skills assessed, regarding the front crawl development. The complex and specific tasks related to the technical crawl stroke (crawl leg and displacement crawl) showed high development.

The criteria used in the evaluation indicate that breaking the touch barrier appeared to influence the development of fluctuation and displacement, in water, with confidence and autonomy. It can represent a better relationship with the group and predisposition for further activities, in the pool. In conclusion, the participants demonstrated improvement in the skills assessed, showing positive results both in the execution and the predisposition to the proposed activities.

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Mirror illusion reduces ipsilateral motor cortical inhibition in healthy young adults: implications for rehabilitation

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Abstract Unilateral strength training is a promising therapeutic strategy to strengthen the contralateral homologous muscles of the resting limb for patients who suffer from unilateral orthopaedic and neurological conditions. It has been previously hypothesized that viewing the exercising hand in the mirror can augment the strength transfer by modulating corticospinal and motor cortical paths. Consequently, the purpose of this study was to elucidate the corticospinal and motor cortical responses to transcranial magnetic stimulation (TMS) in the left flexor carpi radialis (FCR) with and without viewing a mirror; 1) at rest, and 2) during a forceful shortening contraction of the right wrist flexors. Corticospinal excitability and short-interval intracortical inhibition (SICI) of the right primary motor cortex (M1), and interhemispheric inhibition (IHI) from left to right M1 were measured in young healthy right-handed adults (*N* = 27). These responses were recorded in four conditions: at rest and during contractions (at 60% voluntary contraction), with and without viewing a mirror. During the no-mirror condition, neither hand was visible, whereas in the mirror condition, a reflection of the right hand was seen, thereby giving the illusionary view of the left hand. Corticospinal excitability increased almost twofold during contractions but there was no effect of the mirror. However, mirror viewing of the contracting right wrist attenuated SICI with 9% compared with the no-mirror contraction condition (47 ± 18% vs. 38 ± 15%; *P* = 0.023). Viewing the mirror at rest did not affect IHI (*P* = 0.274). It can be concluded that seeing the mirror image of the contracting right wrist modulated a specific inhibitory path, SICI, in the right M1 without modifying IHI at rest. The present study is an initial step towards understanding how, if at all, mirror viewing of forceful dynamic muscle contractions might augment the effects of cross-education.

Keywords mirror training, cross-education, unilateral impairments, force, motor cortex, motor control

Introduction

Cross-education is the performance improvement in the contralateral homologous muscle of the non-trained limb following a period of effortful unilateral motor practice (Zhou 2000). It has been recently hypothesised that resistance exercise used in conjunction with mirror training could augment the effects of conventional cross-education (Zult, Howatson et al. 2013). There is evidence that mirror viewing of hand and finger movements performed at a fraction of the maximal voluntary force can facilitate inter-limb transfer (Hamzei, Lappchen et al. 2012) and ipsilateral corticospinal (Fukumura, Sugawara et al. 2007) and motor cortical excitability

(Shinoura, Suzuki et al. 2008). Unilateral forceful muscle contractions also increase ipsilateral corticospinal (Perez, Cohen 2009) and motor cortical excitability (Sehm, Perez et al. 2010), however, it is unknown if mirror viewing of a slowly moving but forcefully contracting hand can additionally affect corticospinal and motor cortical excitability in the hemisphere ipsilateral to the moving hand. Such information is needed as a first step to explain how the use of a mirror could augment cross-education, which is a viable treatment option for patients with unilateral orthopaedic and neurological impairments (Farthing, Paul Zehr 2014). Therefore, the aim of the present study was to determine the effects of mirror viewing of the resting or forcefully contracting right hand on corticospinal and motor cortical excitability in the resting left flexor carpi radialis (FCR).

Methods

Participants

Twenty-seven right-handed (Oldfield 1971) healthy volunteers (22 men, 5 women) with an mean age, height, mass and body mass index of 27 years (± 7), 1.76 m (± 0.07), 76.0 kg (± 13.0), and 24.4 kg/m^2 (± 2.9), respectively, participated in the study. All participants provided written informed consent to the experimental procedure, which was approved by the University's Research Ethics Committee and in accordance with the Declaration of Helsinki.

Experimental protocol

This study examined the effects of the mirror on corticospinal and cortical excitability using transcranial magnetic stimulation (TMS) recorded from the left FCR at rest and during right wrist flexion performed with a shortening muscle contraction at 60% maximal voluntary contraction. In the no-mirror condition and mirror condition a cardboard wall or a mirror was placed in the sagittal plane between the left and the right forearm, respectively. Corticospinal excitability and short-interval intracortical inhibition (SICI) of the right M1 was evaluated at rest and during contraction of the right wrist flexors and interhemispheric inhibition (IHI) from the left to right M1 was measured during rest.

Statistics

To determine if corticospinal excitability and SICI of the right M1 were different between the four conditions, a repeated-measures ANOVA with four levels (no-mirror rest, mirror rest, no-mirror contraction, mirror contraction) was used. IHI values were not normally distributed, therefore, a Wilcoxon signed-rank test was used to test differences in IHI at rest between the mirror and no-mirror condition. For the repeated-measures ANOVA's a Bonferroni's *post hoc* pairwise comparison followed for significant interactions. Significance was accepted as $P < 0.05$.

Results

Table 1 shows the main characteristics of the four different conditions. Corticospinal excitability increased almost twofold during contractions but there was no effect of the mirror. However, viewing the mirror image of the contracting wrist attenuated SICI with 9% compared with the no-mirror contraction condition (47 ± 18% vs. 38 ± 15%; $P = 0.023$; Figure 1). Viewing the mirror at rest did not affect IHI ($P = 0.274$).

Table 1. Mean and standard deviation of the descriptive data for the four experimental conditions

Condition	SICI[a] (% of control)	Corticospinal excitability (mV)	IHI[a] (% of control)
No-mirror, rest	38.0 (19.6)	0.18 (0.12)	78.9 (25.8)
Mirror, rest	36.3 (20.4)	0.20 (0.13)	72.6 (32.1)
No-mirror, contraction	38.0 (15.4)	0.41 (0.19)*	N/A
Mirror, contraction	46.6 (18.4)†	0.37 (0.19)*	N/A

IHI, interhemispheric inhibition; N/A, not applicable; SICI, short-interval intracortical inhibition; [a], a higher value means less inhibition; *, compared with the resting conditions ($P \leq 0.014$); †, compared with the no-mirror contraction condition ($P = 0.028$).

Conclusion and discussion

In summary, viewing one's own right hand in a mirror, appearing as the left hand, during a forceful muscle contraction, reduces one specific form of intra-cortical inhibition (SICI) in the right-ipsilateral M1 without modifying corticospinal excitability. The use of a mirror also did not affect IHI, the motor cortical inhibition between the two hemispheres, at rest. Under the current experimental conditions, viewing the movements of one's own hand in a mirror seems to affect motor cortical inhibitory networks in the hemisphere associated with the mirror image. Mirror training in this form could be effective in examining the efficacy of resistance exercise to augment cross-education, given that observing the reflections of the active arm superimposed on the contralateral limb reduces the magnitude of inhibition to the inactive limb.

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Exercise training programs to improve hand rim wheelchair propulsion capacity: a systematic review

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Abstract An adequate wheelchair propulsion capacity is required to perform daily life activities. The purpose of this review was to investigate whether different types of exercise training programs are effective in improving wheelchair propulsion capacity. PubMed and EMBASE databases were searched from their respective inceptions to October 2013. Exercise training studies with at least one outcome measure regarding wheelchair propulsion capacity (e.g. power output) were included. To reflect functional wheelchair propulsion, wheelchair propulsion capacity should contain 4 parameters: aerobic capacity, anaerobic capacity, muscular fitness and mechanical efficiency. Articles were not selected on diagnosis, training type or mode. Methodological quality was rated with the PEDro scale, and the level of evidence was determined. The 21 included studies represented 249 individuals with spinal-cord injury (50%), various diagnoses like cerebral palsy, spina bifida, trauma and polio (12%), and able-bodied participants (38%). Studies were divided into 4 training types: interval, endurance, strength, and mixed training. All 8 interval training studies found a significant improvement in endurance wheelchair propulsion capacity. Three out of 5 endurance training studies showed significant positive effects. Methodological quality and level of evidence was generally poor; there were only two randomized controlled trials. Exercise training programs seem to be effective in improving wheelchair propulsion capacity, with interval training as the most promising training type. However, the body of knowledge is remarkably small in wheelchair-users without spinal-cord injury.

Keywords Exercise, physical fitness, wheelchair, physical training, physical capacity

Introduction

Increasing physical activity level is associated with a lower risk of developing cardiovascular diseases. The intensity of wheelchair propulsion in daily life may not put sufficient stress on the cardiovascular system to induce positive health effects. (Janssen et al. 1994) Hence, breaking

through the vicious cycle of deconditioning in manual wheelchair users may require exercise training.

Since manual wheelchair users' primary means of mobility is through hand rim wheelchair propulsion, exercise training should aim to improve hand rim wheelchair propulsion. Wheelchair propulsion capacity reflects functional wheelchair propulsion in this review and contains 4 parameters: aerobic capacity, anaerobic capacity, muscular fitness and mechanical efficiency.

Valent et al. 2007 reviewed studies on the effect of upper-body exercise and focused on persons with spinal-cord injury only. Training of wheelchair propulsion capacity might be beneficial for more diagnostic groups. Therefore, the present review aims to systematically review the literature on the effectiveness of training programs in improving hand rim wheelchair propulsion capacity, including various groups and all types of training programs.

Methods

PubMed and EMBASE databases were searched from their respective inceptions to October 2013. Exercise training studies with at least one outcome measure regarding wheelchair propulsion capacity were included**.** Articles were not selected on diagnosis, training type or mode. Studies were divided into 4 training types: interval, endurance, strength, and mixed training.

Methodological quality was rated with the PEDro scale, which consists of 8 criteria for internal validity and 2 statistical criteria. The level of evidence was classified by means of a grading system developed by the Oxford Centre of Evidence-Based Medicine.

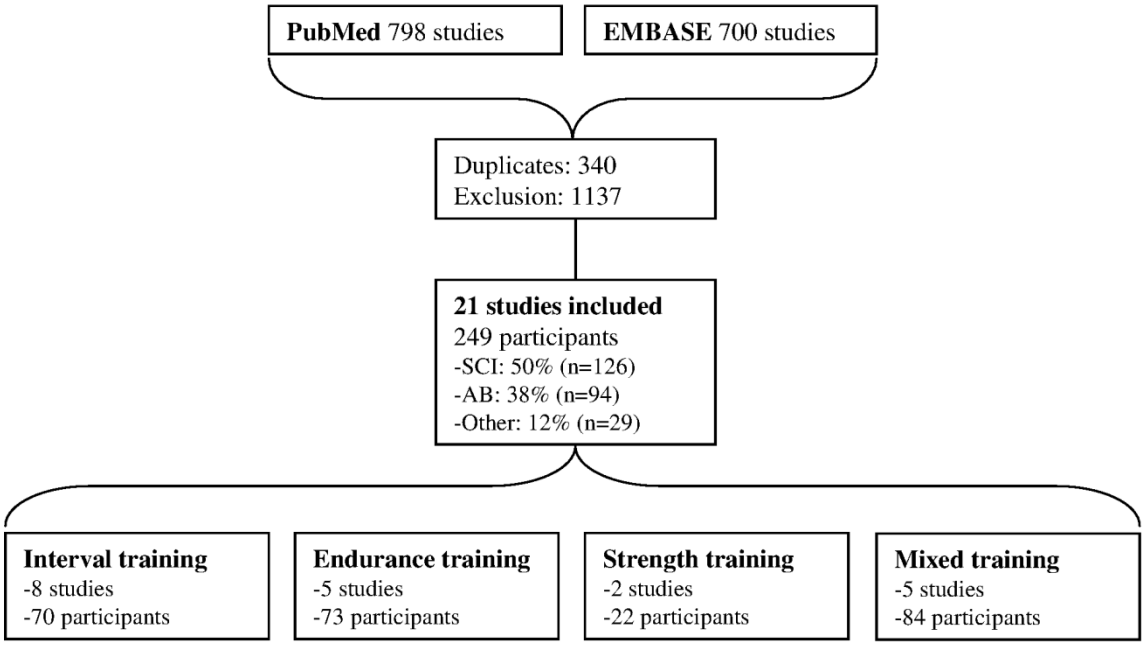

Figure 1. Flowchart for selection of eligible articles. SCI, spinal-cord injury, AB, able-bodied, other, participants having other diseases than spinal-cord injury.

Results

A total of 21 studies were included and divided in different training types (Figure 1). The studies represented 249 individuals; 50% (n=126) diagnosed with spinal cord injury, 38% (n=94) were able-bodied participants and 12% (n=29) were patients diagnosed other than spinal-cord injury.

Exercise training

All interval training studies found a significant improvement in the experimental group, ranging from 18-34% in participants with disabilities and 49-66% in able-bodied participants. Three endurance studies, of which 2 trained able-bodied participants, reported a significant positive effect on endurance outcome measures with an improvement of 30-78%. Both strength training studies reported that sprint propulsion capacity did not improve. A variety of mixed training studies were found; two respiratory muscle training studies showed no positive effects.

Methodological quality

The median PEDro score was 2 out of 10, and no study scored more than 6 points, indicating generally poor methodological quality. Only 2 out of 21 studies were randomised controlled trials. The majority of studies (57%, n=12) consisted of observational studies comparing post-training results with baseline values.

Conclusion and discussion

Although the evidence base is weak, the present review does support exercise training programs as being beneficial for improving wheelchair propulsion capacity. Interval training seems to have the highest potential to improve wheelchair propulsion capacity.

The vast majority of participants involved had a spinal-cord injury or were able-bodied individuals. It is surprising that there were only 2 proper randomised controlled trials. Furthermore, only 5 out of 21 studies reported between-group differences. The majority of studies were case series or even case studies, indicating changes over time that can be due to any factor, There is a need for randomised controlled trials involving manual wheelchair users, particularly including people who do not have spinal-cord injury.

Acknowledgements

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