



Loughborough
University

Peter Harrison Centre
for Disability Sport



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Translation of Sport Science to Paralympic Practitioners

Legacy Document

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Summary 2012-2016

Rio 2016



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'The Peter Harrison Centre is recognised internationally as a centre of excellence, which impacts on the lives of many people. Loughborough University has a world-class sport ecosystem. The Centre's work, through the generous support of the Peter Harrison Foundation, is integral to the University's sporting success and continues to make a unique and life changing contribution to the world of disability sport.'
—

Professor Robert J. Allison
Vice-Chancellor and President of
Loughborough University

INTRODUCTION

Loughborough University's World-leading Research Centre 'The Peter Harrison Centre for Disability Sport (PHC)' located within the National Centre for Sport and Exercise Medicine-East Midlands (NCSEM-EM), is the result of collaboration between academia, industry and the PHC research facility. It is tempting to forget how novel the idea of creating a Research Centre focusing on Disability Sport was back in 2004. The Peter Harrison Foundation (PHF) agreed to an initial five year philanthropic gesture in 2004 and since then has supported the Centre's research and outreach activities spanning areas of rehabilitation sciences, physical activity and Paralympic sport for just over a decade.

The research community supports and enables translational practice in applied sport science through research excellence. Many students at both an undergraduate and postgraduate level have gained valuable vocational skills by working with colleagues associated to the PHC. The PHC's vibrant and supportive environment for research has seen a significant increase in the number of PhD students, post-doctorates and visitors worldwide from as far afield as Japan and Canada. Funding from the PHF has enabled us to: i) prioritise research that will have a significant impact; ii) align our research to 4-year Paralympic cycles; iii) embed our research within both sport and clinical activities; iv) maintain and develop on-going collaborations with colleagues in established areas of Paralympic sport; and v) extend our research priorities to the Performance Health agenda which is part of the NCSEM-EM's strategy.

The PHC mission

- To improve knowledge about Paralympic sport and to promote the substantial health and quality of life benefits that can be gained through participation in disability sports and physical activity.

The PHC aims

- Generate and extend the knowledge in disability sport through applied research.
- Assist in the development of evidence-based practice in disability sport and leisure.
- Ensure that significant research findings are translated into practical outputs and guidelines to help inform disability / medical practitioners attached to sports and rehabilitation centres both nationally and internationally.
- Enhance the national and international focus for disabled sport and leisure.
- Ensure that information and support is provided through the PHC website, newsletters, seminars, workshops and social media.

The PHC objectives

- To improve knowledge and understanding of Paralympic sport. In addition to researching high performance disability sport, the PHC promotes the substantial health and quality of life benefits that can be gained through participation in grassroots disability sport and physical activity.

This legacy document provides an overview of the support and research projects conducted by the PHC over the last Paralympic cycle (2012-2016). Our work has been conducted with participants and athletes across the spectrum from rehabilitation through to elite sport. This document outlines our research themes throughout the London-Rio Paralympic cycle and aims to present the findings in a usable format for all. It also highlights the PHC's passion for advancing research in disability sport. Within this legacy document you will find a summary of each study conducted over the last four years and a flavour of the other activities the PHC have been involved in. Furthermore, we have highlighted some on-going and future work taking place at the centre. If you require more detailed information regarding any of our research or activities, or wish to sign-up to our newsletter, please don't hesitate to contact us using the details below.

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Further contact details on back page.
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Professor Robert Allison with Sir Peter Harrison at the official opening of the National Centre for Sport and Exercise Medicine-East Midlands, the home of the PHC.

EIS MEMORANDUM OF UNDERSTANDING

The PHC signed a Memorandum of Understanding with the English Institute of Sport (EIS) with an agreed ambition to 'advance practice and understanding of Paralympic sports science with a view to enhancing Great Britain's future Paralympic medal prospects.'

The PHC acknowledges the unique skills and expertise that EIS practitioners can provide and have therefore collaborated on a number of applied research projects (e.g. Project PRISM (pages 59), with the delivery of workshops such as the recent one on 'The Paralympic Athlete: An applied perspective' for the British Association of Sport and Exercise Sciences (BASES) (page 67), and the development of a BASES expert statement on the assessment of exercise performance in athletes with a spinal cord injury (page 66). This partnership has also led to the delivery of two very successful UK High Performance Conferences for Paralympic Sport Science and Medicine in conjunction with UK Sport and the British Paralympic Association (BPA).



CONTRIBUTORS 2012-2016

Professor Vicky Tolfrey

Professor in Applied Disability Sport, Director of the PHC and leader of the Sport Performance strand of the PHC



Research interests: Disability sport, wheelchair propulsion kinematics, elite sports performance physiology, exercise testing and interpretation, training and performance.

Vicky has several on-going international collaborations in disability sport, which include work in The Netherlands, Canada and Japan. Most notably she was the Principle Investigator of the applied physiological support programmes that helped the GB wheelchair Rugby and Paratriathlon squads with their preparations for Rio 2016. Vicky was also a member of the Paralympic Performance Advisory Group (PPAG) for ParalympicsGB.

Dr Christof Leicht

Lecturer in Exercise Physiology and current leader of the Health and Wellbeing strand of the PHC



Research interests: Exercise immunology in wheelchair athletes, hot water immersion, modes of exercise.

Christof's most recent book chapter on "The Effect of Acute and Chronic Exercise on Inflammatory Markers in SCI" in the book "The Physiology of Exercise in Spinal Cord Injury" brings together the themes of disability, exercise and inflammation. Christof continues to investigate ways to improve the risk marker profile for chronic disease in populations that have restrictions in their capability to exercise.

Dr Anthony Papathomas

Lecturer in Sport and Exercise Psychology and oversees the PHC's psychosocial programme of research within the Health and Wellbeing strand.



Research interests: Exercise promotion, disordered eating, disability, mental health, social inequality, narrative enquiry.

Anthony's recent book, "The Very Alternative Guide to Spinal Cord Injury", translates academic research into a commercial, mass-market product of the self-help genre. Mental Health strand leader for the British Association for Sport and Exercise Sciences (BASES). Editorial board member for Psychology of Sport and Exercise.

Professor Brett Smith

Reader in Qualitative Health Research



Research interests: Disability, health and physical activity, qualitative research and narrative inquiry, Paralympic identities, retirement from sport.

Brett is now a Professor in the University of Birmingham's School of Sport, Exercise and Rehabilitation.

Dr Barry Mason

Senior Research Associate



Research interests: The physiological and biomechanical demands of wheelchair court sports, Paralympic classification in Wheelchair Rugby and Basketball, wheelchair and handbike configuration for optimal health and performance, indoor player tracking.

Barry has been instrumental in the coordination of many of the PHC's International research projects.



Dr Lettie Bishop

Reader in Exercise Physiology

Research interests: The effect of exercise on cellular and mucosal immune function in addition to interactions between exercise, immune function and inflammatory responses in healthy individuals and in those with chronic conditions.



Dr Keith Tolfrey

Reader in Paediatric Exercise Physiology/PHC Statistical Advisor

Research interests: Health in young people (children and adolescents) and the influence of structured exercise training or regular physical activity of endurance performance, wheelchair sports performance, fat metabolism, postprandial lipaemia, estimation of energy expenditure, research methods.



Dr Jan van der Scheer

Post-doctoral Researcher/Translation Scientist at the NCSEM-EM

Research interests: Physical activity guidelines for individuals with a spinal cord injury, knowledge translation, shoulder health, blood pressure and brain flow, low-intensity exercise in wheelchair users with a spinal injury.



Dr Terri Graham-Paulson

PhD student / Research Assistant

Research interests: Nutritional supplementation habits, perceptions and efficacy in athletes with physical impairments, caffeine, hydration, body composition.

Also works as a Performance Nutritionist for the English Institute of Sport (EIS), British Athletics and the England and Wales Cricket Board.



Dr Thomas Paulson

Research Associate/GBWR Sports Scientist

Research interests: Supporting the prescription of exercise in SCI populations, immune health, ratings of perceived exertion as a tool for self-regulation, impact of exercise modality, shoulder health, functional electrical stimulation.

Currently works as a Senior Pathway Scientist with the English Institute of Sport (EIS).



Katy Griggs

PhD student / Information Officer / Research Assistant

Research interests:

Thermoregulatory responses of wheelchair athletes, cooling strategies. Recently moved to work as a Research Assistant in the Design School at Loughborough University.



Dr John Lenton

Research Technician

Research interests: Wheelchair propulsion techniques, wheelchair configuration, ratings of perceived exertion, classification.

Currently works as Great Britain the Para-cycling Pathway Manager.

CONTRIBUTORS 2012-2016



Mike Hutchinson

PhD student/Research Assistant

Research interests: The application of subjective ratings of perceived exertion during upper-body exercise, hydration.

Also works as a Performance Nutritionist with the England and Wales Cricket Board.



Ben Stephenson

PhD student

Research interests: Longitudinal tracking of mucosal immune function, methods of training load quantification to predict illness and injury, heat acclimation strategies to optimise performance, caffeine.

Also works as a Physiologist for the Great Britain Paratriathlon squad.



Ben Stone

PhD student

Research interests: Handbike set-up for optimal performance, optimising performance from a biomechanical and physiological perspective.



Sven Hoekstra

PhD student

Research interests: The inflammatory response to different strategies to improve health in populations that rely on their upper-body for exercise (e.g. individuals with a spinal cord injury and the elderly) such as hot water immersion or handcycling.



Emma Richardson

PhD student

Research interests: The impact of disabled gym instructors, narrative inquiry, exercise and health psychology and well-being.

Emma now works as a Research Associate at the University of Alabama (USA).



Dr Paul Sindall

PhD student

Research interests: Physiological demands and court-movement patterns of wheelchair tennis, with a particular interest in developmental players.

Currently works as a Senior Lecturer at Salford University.



Dr James Rhodes

PhD student

Research interests: Indoor player tracking system, demands of wheelchair rugby, performance indicators, athlete monitoring.

Currently works as a Sports Scientist for STATS, a sports data and technology company.

AFFILIATIONS

Prof Lucas van der Woude is a visiting Professor to the PHC. He is based in 'Human Movement, Rehabilitation and Functional Recovery' at the Center for Human Movement Sciences of the University Medical Center, University of Groningen, The Netherlands.

Dr Riemer Vegter is a visiting Fellow to the PHC and is an Assistant Professor in 'Human Movement, Rehabilitation and Functional Recovery' at the Center for Human Movement Sciences of the University Medical Center, University of Groningen, The Netherlands.

Prof Kathleen Martin Ginis is a visiting Professor to the PHC. Dr. Martin Ginis is a Professor at the University of British Columbia (Canada), and is the Director of SCI Action Canada, a national alliance of community-based organisations and university-based researchers working together to advance physical activity participation in people living with spinal cord injury.

Prof Maureen MacDonald is a visiting Professor to the PHC and works at McMaster University in Canada as the Director of the School of Interdisciplinary Science. In 2016 Maureen assisted in hosting Post-doctoral Fellow Jan Van de Sheer at McMaster and PhD student Mike Hutchinson in her lab from May to June 2016.

Dr Andrea Bundon returned to Canada in 2016 and started work in the School of Kinesiology at the University of British Columbia. She completed project PRISM, which was a joint venture between the English Institute Sport and the PHC investigating the out of sport transitions and retirements of GB's Paralympic athletes. She is now working with Barry Mason and Vicky Tolfrey on a wheelchair basketball project.

Dr Claudio Perret (Swiss paraplegic Institute): External PhD advisor to Terri Graham-Paulson.

Dr Mike Price (Coventry University): External PhD advisor to Katy Griggs.

Professor George Havenith: PhD supervisor for Katy Griggs.

VISITING RESEARCH PERSONNEL

Dr Tamae Yoda (Assistant Professor in the Department of Interdisciplinary studies at Dokkyo University) (Postdoctoral visitor, 2014).

Tamae assisted PHC members with various laboratory testing whilst visiting and was also able to perform her own research. Her project investigated thermal perceptions of individuals with a spinal cord injury.

Marrit Lemstra (PHC MSc Intern, 2013)

Marrit assisted Barry Mason and Vicky Tolfrey with an RGK supported project assessing the impact of wheel stiffness on physiological demand. The wheels were tested in the laboratory and in a field-based environment.

Annika Willems (PHC MSc Intern, 2013)

Annika was involved in two studies during her time at the PHC, both involved working with the GB Wheelchair Rugby squad. She investigated the use of various methods of body composition assessment in these wheelchair athletes. Furthermore, Annika assisted Katy Griggs investigating the effects of different cooling strategies on the performance and thermoregulation of the Wheelchair Rugby players.

COLLABORATORS



FUNDERS

The PHC would like to say a big thank you to all those that have helped to fund the on-going impactful research and dissemination of findings throughout the last 4-year Paralympic cycle. Most importantly, the PHC would like to thank the Peter Harrison Foundation (PHF) for their enduring support and funding throughout this period; without which the PHC could not continue.



Wakayama Medical University Medical Center for Health Promotion and Sport Science
Joint Usage/Research Center of Sport for Persons with Impairments

SPORT PERFORMANCE

The Peter Harrison Centre for Disability Sport Laboratory

The GB Wheelchair Rugby squad have been involved in applied research projects at the PHC since 2008 and Dr Tom Paulson was embedded as their Physiologist 2013-2016. Both Elite Performance and Development squad members received regular laboratory and field testing to monitor the players' physiological profiles through the Paralympic cycle.



'Over the last 4 years the Physiology support we have had has been world class and I believe it has played a big part in our rapid progress. The combination between lab testing and regular on court testing was key to tracking individual and team progress. This linked with the close relationship with our strength and conditioning coach meant our training program was tailored to make the most of our time and to peak for major competitions. The future support using information gained from the shoulder health research will also help with chair set up and seating position to improve performance and ultimately reduce the impact on our shoulders to reduce injury.'

Gavin Walker
Paralympic Wheelchair Rugby athlete

The PHC has provided physiology support to the Paratriathlon squad since 2013 and Ben Stephenson has been embedded as their Physiologist since 2015. All athletes attend the laboratory for benchmarking ~3 times per year to monitor their progress and assess the impact of training on performance. The assessments include submaximal and maximal testing (cycling and/or running), swim step tests including lactate monitoring, and performance trials e.g. 20 km cycling time trials. Following a needs analysis with the coaches some individual athletes also use the laboratory to perform training in a controlled environment.

'The work of the PHC was instrumental to our success at the Rio 2016 Paralympics. I've been working with them for the last 2 years and the depth of knowledge of all the scientists in particular Ben Stephenson and Terri Paulson has been outstanding and helped me to understand the work being done. Routine tests and training sessions in the lab during the early part of the season definitely helped me win my first World Paratriathlon race in Australia. I'm excited to see how the work with the PHC can progress.'

George Peasgood
Paralympic Paratriathlete

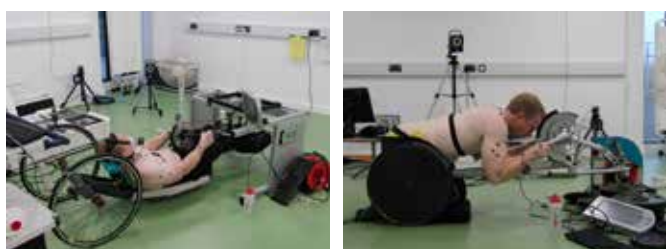




The PHC were proud to support GB's Para-Alpine ski team pre and post their amazing success at the Sochi 2014 Winter Games. Members of the team attended the PHC laboratory for physiological profile testing geared towards monitoring their fitness throughout the year and to allow support staff to tailor their training programmes accordingly.

Following their Paralympic Gold medal Charlotte Evans (guide for visually impaired Kelly Gallagher) commented

"It's never an individual medal or a single win. It's a team effort. There are a lot of people involved in getting you there and the PHC has played a major part in letting us be able to see how fit we are throughout the season."



The PHC welcomed Alan Grace into the lab for 2 days testing as part of his preparations for a second attempt at the World Human Powered Speed Challenge. Alan used two handbike set-ups; kneeling and recumbent during aerobic and anaerobic testing to help confirm which he should use during his record attempt.

England and Wales Disability Cricket – Nutrition support

The PHC established an exciting relationship with England and Wales Disability Cricket in 2013. As part of this relationship the PHC delivered a nutritional education programme to their newly formed regional development centres in Manchester, Northampton and South Croydon. The initial set-up involved the educational sessions being delivered by 3 Loughborough University MSc students, which allowed these individuals to gain experience in an elite disability setting. Once the players had developed their basic knowledge and skills the ECB employed 3 performance nutritionists at a regional level managed by Terri Graham-Paulson; while Terri, Mike Hutchinson and former PHC member, Louise Croft continue to work with the National squads (Physical disability, Blind, Deaf and Learning Disability).



England Physical Disability squad won the inaugural International Committee of the Red Cross T20 World Cup in Bangladesh, 2015.

"Loughborough University has played an integral role in supporting both the Regional Centres and the national disability squads. The England sides are clearly showing enhanced levels of fitness and preparation when compared to their opposition. The impact of Terri's team on the performance end of the disability cricket pathway is clear and all at ECB are looking forward to seeing the fruits of this initiative well into the future."

Ian Martin
Head of Disability Cricket

Um mundo



'Teamwork is essential for the day to day operation of the PHC'

Prof Vicky Tolfrey

THE PETER HARRISON CENTRE FOR DISABILITY SPORT IN BRAZIL

3rd International Convention on Science, Education and Medicine in Sport (ICSEMIS), Santos, São Paulo 2016.

This year's ICSEMIS conference (31st August – 4th September) was held in Santos, Brazil keeping to the tradition of being held in the same country as that year's Olympic and Paralympic Games. The conference was multidisciplinary and thus offered an eclectic mix of presentations ranging from immunology to sociology whilst also permitting a multinational presentation roster.

With the conference only occurring every four years it provides an opportunity for research to be presented from the passed Olympiad. Also, due to the IPC's connections to the event, there is a great deal of Paralympic-specific research on show. This year several world-leaders in Paralympic athlete research convened to recap their work from the previous four year cycle. Of note were Professor Vicky Tolfrey's presentations on nutritional and thermoregulatory considerations for Paralympic athletes and how this may differ compared to their able-bodied counterparts. Nutritional factors were also discussed by Professor Thomas Janssen and Dr Joelle Flueck. Further, biomechanical issues were presented by Dr Reimer Vegter in his discussion of asymmetry in wheelchair propulsion.

All of the work presented with a Paralympic focus has the potential to be applied by current athletes and support staff in an attempt to maximise performance. This will continue through into the next cycle whereby research advancements can be transferred into the applied setting to continually benefit Paralympic athletes.



Image: Simon Bruty / OIS





GB athlete Jim Roberts going head to head with Australia's Chris Bond at the Rio 2016 Paralympics.

Image: Bob Martin / OIS

Wheelchair Rugby support at Games time

The Peter Harrison Foundation grant support was vital for the Great Britain Wheelchair Rugby (GBWR) World Class Performance Programme (WCPP) to create a network of sports science support, research and innovation in the build up to the Rio 2016 Paralympic Games. Dr Tom Paulson completed his PhD with the PHC in 2013 and was bought in to support the strategic development and applied delivery of Sports Science Support specific to Wheelchair Rugby. The support provided to GBWR has helped to significantly shape and develop individual performance plans for players as well as provide measurable and objective feedback to the coaching team to help develop the GB team for the Rio 2016 Paralympic Games.

The key delivery areas included:

- i. Physical performance profiling of Elite squad members to guide training prescription and physical preparation within the multi-disciplinary team.
- ii. Create a sport and impairment-specific 'Fit and Healthy Athlete' education series to prepare robust athletes capable of competing at the elite level.
- iii. Develop an innovative programme of applied research in collaboration with the PHC, including the quantification of on-court training load using a radio frequency-based tracking system and functional electrical stimulation to improve lower-limb skin health in athletes with a spinal cord injury.

One of Dr Paulson's major responsibilities was to develop a clear laboratory and field based performance profiling strategy to provide other practitioners and coaching staff with relevant and meaningful athlete feedback against individual performance plans in the lead up to Rio. The battery of tests has allowed a systematic collection of performance data specific to Wheelchair Rugby at key stages through each yearly training cycle and the optimisation of individual training plans. As well as assessing the players' readiness to compete at major competitions, the profiling data has acted as a guide for the development of a long-term talent profiling tool to support the recruitment and development of athletes who will compete at Tokyo 2020 and beyond.

Tom travelled with the squad to the Rio Test event (Feb, 2016) and worked closely with the multi-disciplinary team in the lead up to the Games where his responsibilities included:

- Implementation of a travel fatigue and wellness questionnaire to highlight athletes who may require individualised acclimation and travel strategies for the Games.
- Hydration monitoring throughout travel and training
- Observe and monitor athletes and staff to highlight challenges and priorities for Games time.
- Manage and deliver the individual player review system whereby players were benchmarked against key sport-specific competencies and given individual development plans for achieving medal success.
- Use data to schedule and plan the taper and pre-competition training phase of the Paralympic plan to ensure athletes arrived in Rio ready to compete.
- Design of impairment-specific recovery and nutrition strategies for key members of the squad who played multiple games during the Paralympics.
- Build and manage an external relationship with Kurio compression to provide made to measure compression garments for the squad.

Belo Horizonte ParalympicsGB preparation camp

Terri Graham-Paulson undertook the role of HQ Coordinator at the ParalympicsGB preparation camp in Belo Horizonte. Belo provided athletes with world class sporting facilities, accommodation and support services. It also provided the athletes with an opportunity to acclimatise because it was in the same time zone and had similar climatic conditions to Rio de Janeiro. The role of preparation camp staff was to provide an efficient and professional service to ensure athletes could complete their final preparations leading into the Games. This involved simple things such as organising transport links between training facilities, ensuring bedroom set-up was appropriate, facilitating off-site visits/training, providing nutritious meals, policing hand hygiene to help prevent illness, organising meetings and importantly, ensuring there were opportunities for rest and relaxation. As in London 2012, the Rio 2016 volunteers were invaluable in helping staff to converse with hotel and training venue staff to ensure everything ran as smoothly as possible.



Terri and Jo Wright (BPA) with Rio 2016 volunteers



Belo Horizonte Preparation Camp support team

Paralympic debut for triathlon in Rio 2016

The inclusion of Paratriathlon in Rio marked a huge step forward for the sport and ParalympicsGB as a team of 11 British athletes and 2 guides aimed to follow in the footsteps of Vicky Holland and the Brownlee Brothers' success just weeks earlier.

As part of his PhD, Ben Stephenson provided physiology support to the British Paratriathlon team in the year leading into the Games. This involved the organisation of lab-based physiology screening, analysis and management of athletes' training loads. This embedded scientist approach allows the translation of applied research findings to guide coach and practitioner delivery on the ground to directly support athlete performance.

Ben also led a project on pre-competition heat acclimation to help the athletes deal with the potential heat of Rio. A novel method using mixed active and passive heat acclimation was chosen to help members of the Great Britain Paratriathlon team. Passive acclimation, in the form of ambient heat exposure immediately after exercise draws on work from Zurawlew et al. (2015) where heat adaptation was shown following six days of hot water immersion post-exercise. Active acclimation sessions were heart rate controlled and therefore minimised the need to continually measure core temperature. This protocol was conducted over 8 successive days and contained 3 passive heat exposures, immediately after training sessions whereby athletes core and skin temperature were already elevated. This was designed to have minimal impact on athletes' pre-competition routines that exercising in the heat every day may have, which is especially relevant in a multi-modality sport such as Triathlon.



Ben with PT5 silver medallists Hazel and Alison

The Paralympic race was contested over the triathlon sprint distance (750 m open water swim, 20 km cycle or handcycle, and 5 km run or wheelchair race). Saturday saw the British men's team do battle across three race categories, PT1 (wheelchair users), PT2 (severe impairment) and PT4 (mild impairment), under conditions of around 25oC. Andy Lewis became the first British Paralympic Triathlete to win a medal at the Games with a dominant performance to win gold in the PT2 category. The crowds were also treated to incredible performances from big names such as Jetze Plat (NED) and Martin Schulz (GER). The following day Britain's women competed as temperatures rose to 31oC, but these were conditions that they had prepared for with Ben. Lauren Steadman won PT4 silver while visually impaired athletes, Alison Patrick (guided by Hazel Smith) and Melissa Reid (guided by Nicole Walters) won silver and bronze medals respectively. The conditions were tough on race day and hence the pre-acclimation of athletes in Loughborough and acclimatisation at the Belo Horizonte preparation camp were essential.

Ben Stephenson and Vicky Tolfrey attended the Paratriathlon events and noted that it was brilliant to see such a well organised event with spectators lining Copacabana beach, most of who were viewing the sport for the first time. Vicky spoke with Sir Phillip Craven and his wife and both were most notably impressed with the performance of the GB athletes. The British team's achievements, and the success of Paratriathlon as a spectacle in Rio, will hopefully provide a springboard as we go into the Tokyo 2020 cycle.



Vicky with Sir Phillip Craven and his wife Jocelyn



Jonathon Riall with Paralympic Gold medallist, Andy Lewis

'The partnership between the Peter Harrison Centre and the British Paratriathlon team has grown and developed steadily over the past 3-4 years, which culminated in an effective and seamless support to athletes in the lead up to the sports first Paralympic Games in Rio 2016. Over the past 15 months the sport has had a Peter Harrison PhD practitioner embedded into the sport in Ben Stephenson. Ben has taken the lead on creating a foundation for two things, world class support to athletes, and collecting data to create useful and meaningful research. In the lead up to the games Ben was a key part of the multi-disciplinary team, attending all team meetings and inputting thought and consideration into all athletes plans. However the real impact from Ben was seen both in the lab, and with athletes and coaches trying to bring to life what physiological testing results meant and further applying them to their training. Ben also led on all heat preparation strategies for the Games which saw a large percentage of athletes complete a protocol of training in the heat to be able to cope best with the predicted climate in Rio. Ben, supported fully by Vicky Tolfrey and her team, went above and beyond to ensure all athletes had the very best support, and this was demonstrated nowhere better than for Alison Patrick and Hazel Smith, who for injury rehabilitation reasons, stayed in the UK longer than the rest of the team, and in this time had first class support facilitated by the PHC team to access appropriate training, heat acclimatisation and coaching support. The results in Rio, which saw the British team collect medals across more categories than any other nation, could not have been delivered without the support this partnership has provided.'

Jonathon Riall
Paratriathlon Head Coach

Testing a proposed Paralympic classification system for va'a

In recent years, the International Paralympic Committee (IPC) has highlighted the importance of an evidence-based classification system for all athletes with physical impairments to control the impact of impairment on the outcome of competition (Tweedy and Vanlandewijck, 2011). The International Canoe Federation (ICF) therefore initiated a research project to evaluate, develop and present a proposal to the IPC relating to a valid and evidence-based classification system for para-va'a.

PHC members Vicky Tolfrey, Barry Mason and Mike Hutchinson were involved in the research which aimed to define the sport-specific range of movement in the trunk, upper and lower limbs, and to determine the power output during va'a paddling in elite able-bodied and para va'a athletes. This enabled the research team to determine the impact of impaired range of movement and loss of strength on an athlete's ability to paddle. The findings assisted the team in determining the number and definition of the classification groups and hence the minimal eligibility criteria and classification tests used for va'a athletes in the future.

The research team collected data from 10 elite able-bodied and 29 para-va'a athletes at the Swedish School of Sport and Health Sciences (GIH). PHC members accompanied the GB athletes to Sweden for their testing and performed the analysis on the entire cohort.

Since completion of this work Johanna Rosen has been successful in obtaining funding to support her PhD studies with main supervisor Professor Toni Arndt and co-supervisors Dr Anna Bjerkefors and Professor Vicky Tolfrey. The PHC look forward to sharing Johanna's results with you in the near future.



PERFORMANCE SPORT

Thermoregulatory responses during competitive Wheelchair Rugby match play

Introduction

Wheelchair Rugby was originally developed for individuals with tetraplegia. However, recent changes to the International Wheelchair Rugby Federation (IWRF) classification system have meant that individuals with other physical impairments, such as cerebral palsy, multiple amputations and neuromuscular disease - are now eligible to compete.

Studies have shown IWRF classification to be closely related to the volume of activity elicited over a typical Wheelchair Rugby quarter. Yet, despite the noted thermoregulatory impairment of individuals with tetraplegia, no study to date has examined the combination of thermal strain of these players during match play and the associated activity profiles. The purpose of this study was to determine whether a player's physical impairment or activity profile was related to the amount of thermal strain experienced during Wheelchair Rugby match play.

Methods

17 elite Wheelchair Rugby players played a competitive match, whilst activity profiles, measures of core and skin temperature, heart rate and perceptual responses were recorded. Players were divided into two groups depending on their physical impairment; players with a cervical spinal cord injury, (SCI, n=10) or non-spinal related physical impairments (NON-SCI, n=7).

Main findings and applications

- The change in core temperature over the course of the match was significantly greater in SCI.
- SCI experienced greater thermal strain than NON-SCI players despite covering ~17% less distance and pushing on average ~10% slower.
- SCI were under a greater amount of thermal strain compared to their NON-SCI teammates mainly due to the reduction in heat loss capacity as a result of their impairment and not the amount of work performed.

Reference

Griggs, K. E., Havenith, G., Price, M. J., Mason, B. S. and Goosey-Tolfrey, V.L. Thermoregulatory Responses during Competitive Wheelchair Rugby Match Play. *International Journal of Sports Medicine*. Int J Sports Med. 2017 Feb 13. doi: 10.1055/s-0042-121263. [Epub ahead of print].



PERFORMANCE SPORT

Cooling athletes with a spinal cord injury

Introduction

Despite the interest and vast array of research into cooling strategies for the able-bodied athlete, less is known regarding the application for thermoregulatory impaired athletes with a spinal cord injury (SCI).

This review was undertaken to examine the scientific literature that addresses their application of cooling strategies in individuals with a SCI. Each method is discussed in regards to the associated practical issues and the potential underlying mechanism.

Methods

A comprehensive literature search was conducted using the key terms 'cooling', with 'sport', 'Paralympic', 'wheelchair sport', 'exercise', 'performance', with 'spinal cord lesion', 'spinal cord injury', 'tetraplegia', 'quadriplegia' and 'paraplegia'. The inclusion criteria comprised studies that reported a population group of individuals with a SCI, use of cooling strategies with exercise and articles that were published in English-language peer-reviewed journals.

Main Findings

- According to the 10 studies reviewed, wearing an ice vest during intermittent sprint exercise both reduces thermal strain and enhances performance.
- A combination of pre-cooling and cooling during exercise, or half-time cooling may be an effective strategy.
- Cooling strategies for athletes with a SCI should be individualised to account for the level and completeness of the lesion, while also considering the specific regulations and logistics of the sport involved.
- Future studies are needed to ensure that research outcomes can be translated into meaningful performance enhancements by investigating cooling strategies under the constraints of competition.

Reference

Griggs, K.E., Price, M.J. and Goosey-Tolfrey, V.L. (2015). Cooling athletes with a spinal cord injury. *Sports Medicine*. 45(1): 9-21.



PERFORMANCE SPORT

A novel indoor tracking system to explore the demands of wheelchair sports

Introduction

Understanding the physical demands placed on athletes during competition is a key requirement to help practitioners prescribe specific, individualised training programmes.

In able-bodied team sports this information is typically obtained using Global Positioning Systems (GPS). However, indoor team sports such as Wheelchair Basketball and Rugby cannot utilise GPS since it does not operate indoors. Therefore, this study sought to explore the accuracy and reliability of a radio frequency based indoor tracking (ITS) for use with the wheelchair court sports.

Methods

One able-bodied participant experienced with wheelchair propulsion performed a series of field tests on a Wheelchair Basketball court. Performance measures including mean and peak speeds reached and distance covered were monitored by the ITS, and were compared against a laser total station and an inertial sensor (criterion measures).



Main Findings and applications

- The static error of the ITS was between 19-32 cm
- During dynamic tasks specific to wheelchair sports the relative errors for distance covered and peak speed never exceeded 1.3 and 2.0%, respectively.
- Accuracy reduced at a lower sampling frequency (4 Hz).
- The ITS was deemed an acceptable and reliable tool for tracking wheelchair sports activities at frequencies of 8 or 16 Hz.

Reference

Rhodes, J., Mason, B., Perrat, B., Smith, M. and Goosey-Tolfrey, V. (2014). The validity and reliability of a novel indoor player tracking system for use within wheelchair court sports. *Journal of Sports Sciences*. 32: 1639-1647.

Dr Rhodes' studies above and on page 25 were collaborative projects with the English Institute of Sport, McLaren Applied Technologies and the University of Nottingham, who have facilitated developments to the tracking system to help extract data meaningful to the sports in a practical and timely manner. Their support is greatly appreciated.



PERFORMANCE SPORT

Miniaturised data loggers and radio frequency systems for tracking wheelchair activities

Introduction

A radio-frequency based indoor tracking system (ITS) has recently been validated as an accurate and reliable system for quantifying the external demands of wheelchair sports.

Unfortunately the ITS can take a long time to install and calibrate, therefore it does have its limitations for use within elite sport. Wheel mounted miniaturised data loggers (MDL) offer a more practical solution however their accuracy and reliability has yet to be determined in relation to a valid criterion measure.

Methods

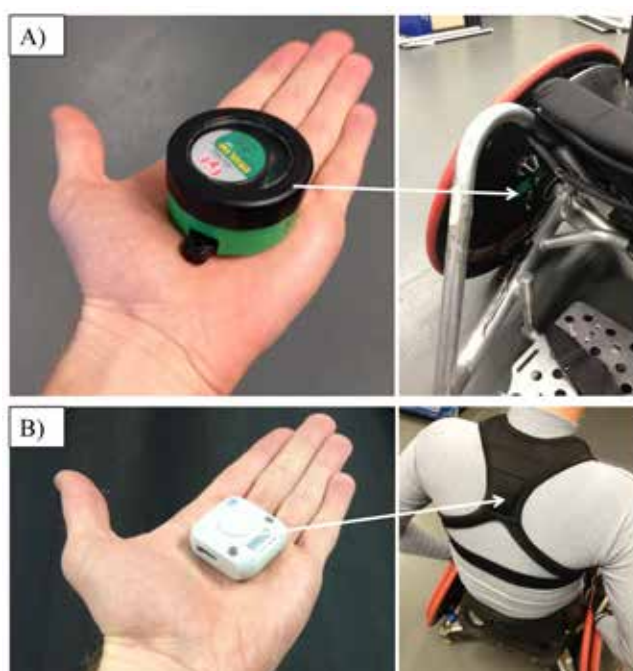
11 international Wheelchair Rugby players were monitored during 4 Wheelchair Rugby matches via the ITS and MDL (see figure). The MDL was sampled at both 1- (MDL-1) and 5-sec (MDL-5) intervals. During games the distance covered, peak speeds and times spent within arbitrary speed zones were collected and analysed.

Main Findings

- No significant differences were observed between devices for the distances covered. Although no significant difference existed between MDL-1 and the ITS for the detection of peak speeds, MDL-5 significantly underestimated peak speeds.
- Large random errors in the time spent in arbitrary speed zones were observed, particularly for MDL-5.
- Although the MDL offers a practical alternative to the ITS and may be acceptable for quantifying the volume of activity during wheelchair sports, it should not be used to represent the high speed activities associated with wheelchair sports, especially at 5-sec intervals.
- The MDL (top) and where it attaches to the wheelchair, and the tags of the ITS (bottom) and where they were worn by players.

Reference

Mason, B., Lenton, J., Rhodes, J., Cooper, R. and Goosey-Tolfrey, V. L. (2014). Comparing the activity profiles of wheelchair rugby using a miniaturised data logger and radio-frequency tracking system. *Biomedical Research International*, Article ID 348048.



PERFORMANCE SPORT

The use of inertial sensors for measuring wheelchair sports activities

Introduction

The use of innovative technology has become a key feature of research that has improved knowledge and performance levels in wheelchair court sports.

The challenge that now faces researchers is to collect scientific data about athletes' performance in an environment that is most relevant for them. For wheelchair court sport athletes this means a shift from laboratory based testing towards field based tests wherever possible. Recently an inertial sensor has been developed to help determine the speed profiles of athletes during over-ground propulsion, which this study aimed to validate.

Methods

A wireless inertial sensor was attached to the axle of a sports wheelchair which was tested at incremental speeds (1-6 $\text{m}\cdot\text{s}^{-1}$) on a motor driven treadmill which had previously been calibrated. The sensor was then assessed for its detection of peak speed during maximal effort sprinting on a wheelchair ergometer compared to high-speed video analysis.

Main Findings

- During incremental testing on the treadmill, systematic bias and random errors never exceeded $0.086 \text{ m}\cdot\text{s}^{-1}$.
- The sensor was also shown to be reliable with coefficients of variation never exceeding 0.9% CV.
- During maximal sprinting the sensors provided a reliable representation of peak speed (<1.6% CV.)
- The inertial sensor tested can be considered an accurate and reliable tool for the assessment of linear wheelchair performance.

Reference

Mason, B. S., Rhodes, J. and Goosey-Tolfrey, V. L. (2014). Validity and reliability of an inertial sensor for wheelchair court sports performance. *Journal of Applied Biomechanics*. 30: 326-331.

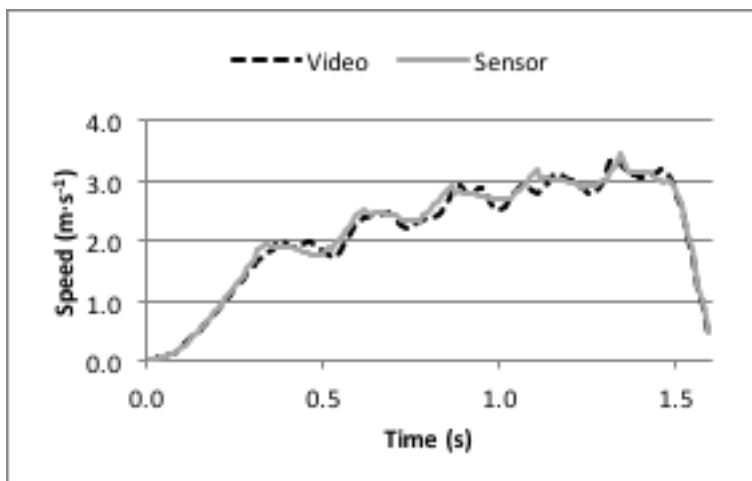


Illustration of the inertial sensor and its attachment to the sports wheelchair (top) and a trace comparing the sensor to the criterion (high-speed video) data.

PERFORMANCE SPORT

The activity profiles of elite Wheelchair Rugby athletes and the effect of team rank on successful mobility performance

Introduction

In order to prescribe athletes with more specific, individualised training programmes we need to understand the demands of the sport, but more importantly how the demands differ between athletes.

In Wheelchair Rugby a classification system exists, which categorises players according to the severity of their impairment. The aims of this research were to establish how the demands of competition varied between athletes of different classification and to understand what successful performance looked like in Wheelchair Rugby by comparing external measures of performance between different ranked teams during competition.

Methods

75 elite Wheelchair Rugby players from 11 international teams were monitored using the ITS across two international tournaments. Players were categorised according to their International Wheelchair Rugby Federation (IWRF) classification system into four groups: I (0.5), II (1.0-1.5), III (2.0-2.5), IV (3.0-3.5). Players were also grouped by team rank (LOW, MID, HIGH) dependent on their teams IWRF world ranking. Performance was determined by the distance players covered, the speeds they reached and the time they spent in various intensity speed zones. Data were reported for individuals who played in full quarters and matches only.



Main findings and applications

- During a typical quarter, higher classification groups covered more distance than lower groups except between III and IV.
- Group IV reached higher peak speeds than all other groups.
- Due to their role as defensive players, Groups I and II spent more time in 'very low' speed zones.
- No significant decline in any performance variable was observed between quarters for athletes competing in full matches.
- Players from LOW teams spent less time on court, which may be due to a lack of physical fitness, as more substitutions were performed by these teams.
- No differences existed between team ranks for the relative distance covered.
- Players from HIGH teams were capable of reaching higher peak speeds and spent more time in high speed zones than MID and LOW teams.

Reference

Rhodes, J. M., Mason, B. S., Perrat, B., Smith, M., Malone, L. A. and Goosey-Tolfrey, V. L. (2014). Activity profiles of elite wheelchair rugby players during competition. *International Journal of Sports Physiology and Performance*. 10: 318-325.

Rhodes, J. M., Mason, B. S., Malone, L. A. and Goosey-Tolfrey, V. L. (2014). Effect of team rank and player classification on activity profiles of elite wheelchair rugby players. *Journal of Sports Sciences*. 33: 2070-2078.

PERFORMANCE SPORT

Individualised internal and external training load relationships in elite Wheelchair Rugby players

Introduction

The quantification and longitudinal monitoring of athlete training load (TL) provides a scientific explanation for changes in performance and helps manage injury and illness risk.

Therefore, accurate and reliable monitoring tools are essential for the optimisation of athletic performance. The aim of the present study was to establish the relationship between measures of internal (heart rate (HR) and session rating of perceived exertion (RPE) (sRPE)) and external TL specific to Wheelchair Rugby.

Methods

14 international Wheelchair Rugby athletes were monitored during 18 training sessions over a 3-month period during the competition phase of the season. Activity profiles were collected during each training session using a radio-frequency based indoor tracking system. External TL was quantified by total distance (m) covered as well as time spent and distance covered in a range of classification-specific arbitrary speed zones. Banisters TRIMP and Edwards summated HR zone (SHRZ) methods were used to quantify physiological internal TL. sRPE was calculated as the product of session duration multiplied by perceived exertion using the Borg CR10 scale. Relationships between external and internal TL were examined using Pearson correlation coefficients and 95% confidence intervals (95% CI).



Main findings and applications

- Each method of internal TL correlated significantly ($p < 0.01$) with the total distance covered during training sessions.
- Large and very large significant ($p < 0.01$) correlations were observed between all measures of internal TL and, times spent and distances covered in low and moderate intensity speed zones.
- Weaker relationships ($r = 0.38 - 0.58$) were observed between internal TL and the number of high intensity activities performed.
- A large variation of within-individual correlation co-efficient was observed between sRPE and all external TL measures.
- The current findings suggest that sRPE and HR-based internal TL measures provide a valid tool for quantifying volume of external TL during Wheelchair Rugby training but may underestimate high intensity activities.
- It is recommended that both internal and external TL measures are employed for the monitoring of overall TL during court-based training in elite Wheelchair Rugby athletes.

Reference

Paulson, T., Mason, B., Rhodes, J. and Goosey-Tolfrey, V. (2015). Individualized internal and external training load relationships in elite wheelchair rugby players. *Frontiers in Physiology*, (6): 388.

PERFORMANCE SPORT

Athletes with tetraplegia achieve their highest heart rates when exercising on court

Introduction

The physiological assessment of highly-trained athletes is a cornerstone of many scientific support programs. It is well known that tetraplegia results in lower maximum heart rates due to the innervation of the heart which is affected by spinal cord injury.

However, in the years that we have tested athletes with tetraplegia we have observed some untypically high heart rates when assessing performance on court.

Methods

We retrospectively reviewed our data on Great Britain Wheelchair Rugby athletes collected during the last two Paralympic cycles. We extracted and compared peak heart rate responses between a standard laboratory-based incremental exercise test on a treadmill and two different maximal field tests (4 min and 40 min maximal push on court).

Main findings and applications

- Both field tests elicited higher peak responses than the laboratory-based test, implying that laboratory-based incremental protocols preclude the attainment of true peak responses.
- This may be due to the different locomotor patterns required to sustain wheelchair propulsion during treadmill exercise or that maximal incremental treadmill protocols only require individuals to exercise at or near maximal exhaustion for a relatively short period of time.
- We acknowledge that both field- and laboratory-based testing have respective merits and pitfalls and suggest that the choice of test be dictated by the question at hand: if true peak responses are required then field-based testing is warranted. On the other hand, laboratory-based testing may be more appropriate for obtaining physiological responses across a range of standardised exercise intensities.

Reference

West C. R., Leicht C. A., Goosey-Tolfrey V. L. and Romer L. M. (2016). Perspective: Does laboratory-based maximal incremental exercise testing elicit maximum physiological responses in highly-trained athletes with cervical spinal cord injury? *Frontiers in Physiology*. 6: 419.



PERFORMANCE SPORT

Sports wheelchair configuration: A review of the literature

Introduction

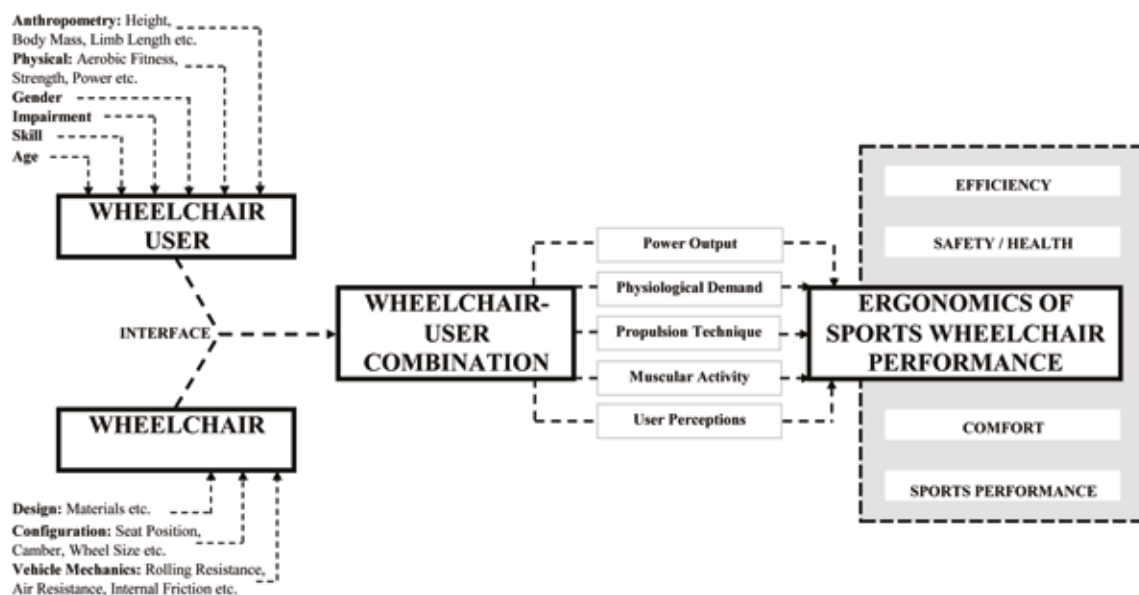
The wheelchair is clearly the most critical part of equipment used by a wheelchair athlete and can have a huge bearing on their sports performance (See figure).

However, scientific literature exploring the performance effects of different configurations has mainly been limited to wheelchairs used for daily-life propulsion. Of the limited literature that has focused on wheelchair sports, it has been difficult to interpret the findings as studies have implemented a vast range of methodological approaches that relate to the type of wheelchair, standardisation methods, participants, testing modality and exercise protocols used. In order to determine reliable cause and effect relationships and most importantly to make research transferable to athletes, coaches and manufacturers, there are a number of steps that researchers must take in the future:

- All testing must take place in a sports wheelchair and not a daily life wheelchair as the settings vary considerably between the two different designs.
- Care must be taken to standardise other areas of wheelchair configuration when manipulating one area.
- Wherever possible, trained wheelchair athletes should be used as participants.
- A combination of laboratory and field based testing should be employed.
- Exercise protocols should be employed that are reflective of the demands of the sports.

Reference

Mason, B. S., van der Woude, L. H. V. and Goosey-Tolfrey, V. L. (2013). The ergonomics of wheelchair configuration for optimal performance in the wheelchair court sports. *Sports Medicine*. 43: 23-38.



Factors influencing mobility performance for wheelchair court sport athletes, highlighting the important role of the wheelchair

PERFORMANCE SPORT

The effect of wheel configuration on Wheelchair Basketball mobility performance

Introduction

There are a wide variety of options currently available to athletes with regards to the type of wheels they select.

Each wheel can differ dramatically in terms of the spoke configuration (number and orientation) and the type of tyre selected (clincher vs tubular). These subtle differences can affect both the stiffness of the wheels and the rolling resistance experienced, and may subsequently have an effect on performance, which is what the current study sought to determine.

Methods

8 able-bodied participants experienced with wheelchair propulsion performed a series of 3-min bouts on a wheelchair ergometer at 2 submaximal fixed speeds using 5 different wheel types, which differed in spoke number, orientation and tyre type and orientation. Wheels were tested in both a new and used condition. Prior to testing the lateral stiffness of each wheel configuration was analysed using a deflection test. During testing, power output and physiological measures (heart rate, oxygen uptake) were recorded in the laboratory. Follow up field-based testing with 3 wheelchair athletes took place to assess the impact of wheel configuration on maximal effort mobility performance.

Main Findings

- Wheels with fewer (24), thicker (4.0 mm) radially orientated spokes demonstrated the greatest stiffness/lowest deflection (Spinergy SLX)
- Wheel stiffness had no significant effect on physiological strain during steady-state wheelchair propulsion
- Physical strain was reduced in wheels configured with tubular tyres owing to the higher inflation pressures and lower resistances they encountered.
- Wheel type had little bearing on linear sprinting performance over-ground.

The deflection test was used to determine the lateral stiffness of different wheel configurations. Incremental weights were placed on the axle of each wheel type, supported at three points on the rim, with deflection measured to the nearest 0.01 mm using a dial test indicator gauge.



Reference

Mason, B. S., Lemstra, M., Vegter, R., van der Woude, L. H. V. and Goosey-Tolfrey, V. L. (2015). Influence of wheel configuration on wheelchair basketball performance: wheel stiffness, tyre type and orientation. *Medical Engineering and Physics*. 37(4): 392-399.



This project was conducted in coordination with RGK wheelchairs, whom we would like to thank for the provision of all the wheels and their technical support throughout the project.

PERFORMANCE SPORT

Expert users' perceptions of racing wheelchair design and set up

Introduction

There is a substantial gap in our understanding of how athletes, their coaches and the manufacturers of racing chairs interpret, adopt, implement, modify or reject research pertaining to wheelchair racing.

The objective of this research was to address this gap and use a qualitative research design to engage directly with expert users (e.g. elite wheelchair racers, their coaches and the manufacturers of racing chairs) and discuss their perceptions of how different aspects of chair design and configuration impact upon athletic performance.

Methods

12 expert users which represented United Kingdom (6), Austria (1), Australia (2), Canada (1) and the Netherlands (1). The sample comprised of 5 current athletes, 4 coaches (including 2 former athletes) and 2 wheelchair manufacturers. A semi-structured interviewing method was adopted to allow the exploration of topics identified a priori by the research team while still providing opportunities for participants to raise new subjects that they felt should also be included. Topics included: the components of racing chairs (bearings, compensators, footrest, frame, push rims, seat, steering, tires and wheels), aspects related to the set-up of the chair (fit and positioning of athlete in chair), and the processes involved in selecting, ordering, being fitted for and/or manufacturing a new chair. Gloves, though not strictly related to chair design were also included because they were deemed integral to the interface between the athlete and the racing chair.

Main findings and applications

- Through interviews and other qualitative methods, expert users are able to comment on the practicality of implementing certain evidence-based recommendations.
- For instance, an athlete raised the issue that while athletes in the T51 class might benefit from the lightness of quad spoke wheels, many used disc wheels because of the danger of catching their hands between the gaps in quad spokes.
- Expert users can play a crucial role in identifying future areas for research.
- This was seen when coaches and manufacturers raised the issue of tyre pressures on a Mondotrack surface.

In short, by engaging with expert users to identify research questions and by drawing on qualitative research designs, we can ensure that our research agendas are aligned with the immediate needs of the populations they are intended to benefit thus enhancing the probability that our research findings will have impact.

Reference

Bundon, A., Mason, B. and Goosey-Tolfrey, V.L. (in press, 2016). Expert users' perceptions of racing wheelchair design and set up: The knowns, unknowns and next steps. Adapted of Physical Activity Quarterly.



PERFORMANCE SPORT

Expert users' perceptions of racing on-going work: Physiological and kinematic screening of trained handcyclists

Introduction

Handcycling has become a popular form of mobility for individuals with lower-limb impairments as a recreational or sporting exercise modality.

In a sporting context, handcycling was first included in the Paralympic Games in 2004 and has been integrated into the International Cycling Union since 2007. In the 2016 Paralympic Games athletes competed in 13 events, 'road races and time trials', across 5 classifications.

Currently, very little is known about how trained handcyclists configure their own handbikes and how this impacts upon their propulsion strategies. The project aims to identify how trained athletes configure their handcycles and to develop a kinematic profile for trained handcyclists.

What does the project involve?

It involves trained handcyclists attending the laboratory to complete a number of physiological and biomechanical tests in their own handbike. The participants complete a submaximal and maximal exercise test to determine their physiological profile. Markers are then attached to the hands, arms and shoulders of the participants to enable upper-limb kinematics to be recorded. The participants' then handcycle at a number of different exercise intensities while upper-limb kinematics are collected.

Future Work

The effects of handbike configuration on performance

Handcycling performance is dependent upon 3 factors:

- The capabilities of the athlete
- The design of the handbike
- The interaction between athlete and handbike

Over the last decade, there have been considerable advances in handbike design and the physical conditioning of elite handcyclists. Yet very little is known about the impact of the interface between the athlete and the handbike on endurance performance and injury risk.



How do we know what to manipulate?

A qualitative study was conducted to explore how expert users (athletes, coaches, manufacturers and members of the athlete support team) perceive the handbike-user interface to impact upon performance (opposite page). Themes emerged regarding a number of critical components of the interface which were thought to impact upon performance and thus warranted future quantitative research.

How will it be investigated?

The identified components will be manipulated independently, under sport-specific conditions in a laboratory, to determine their effects on efficiency. A multidisciplinary approach, involving the measurement of variables such as gas analysis, heart rate, blood lactate concentration, upper-limb kinematics and cycle kinetics, will be employed in order to gain the fullest insight into the impact of handbike configuration on performance.

Why this is important?

The results of this research will enable the handbike-user interface to be optimised with regard to efficiency and performance. Furthermore, the results from this project could also be transferred to the everyday handcyclist enhancing their mobility.

PERFORMANCE SPORT

Similar exercise thresholds for athletes with paraplegia and tetraplegia

Introduction

Lactate and ventilatory thresholds are important markers for exercise intensity and can be used to prescribe exercise, or to monitor the progress of an exercise programme.

The purpose of this study was to find out whether these thresholds would occur at a similar relative exercise intensity in wheelchair athletes with either tetraplegia (wheelchair rugby athletes) or paraplegia (Wheelchair Basketball athletes).

Methods

10 athletes with tetraplegia and 9 athletes with paraplegia performed a standardised incremental treadmill exercise step test to exhaustion. 4 of the most frequent exercise thresholds were determined: the "aerobic" and "anaerobic" blood lactate thresholds, the ventilatory threshold, and the respiratory compensation point (RCP).

Main findings and applications

- The blood lactate thresholds were determined in 34 of 38 cases, ventilatory thresholds and RCPs in 31 of 38 cases.
- Thresholds expressed as the percentage of peak capacity did not differ between athletes with paraplegia and tetraplegia despite altered breathing in the latter, which could theoretically affect ventilatory thresholds.
- Measuring blood lactate leads to a higher threshold determination rate when compared with ventilatory data and therefore has a practical advantage over ventilatory thresholds.

Reference

Leicht C.A., Lavin J. Griggs K.E., Tolfrey K. and Goosey-Tolfrey V.L. (2014). Blood lactate and ventilatory thresholds in wheelchair athletes with tetraplegia and paraplegia. *European Journal of Applied Physiology*. 114(8): 1635-43.



PERFORMANCE SPORT

Field based testing of wheelchair athletes

Introduction

The volume of literature on field-based physiological testing of wheelchair sports, such as Basketball, Rugby and Tennis, is considerably smaller when compared with that available for individual and team athletes in able-bodied sports. In line with the able-bodied literature, it is recognised that performance in wheelchair sports not only rely on fitness, but also sport-specific skills, experience and technical proficiency.

However, in contrast to able-bodied sports, two major components contribute towards 'wheeled sports' performance; the athlete, and the wheelchair. It is the interaction of these two that enable wheelchair propulsion and the sporting movements required within a given sport. Like any other athlete, participants of wheelchair sports are looking for efficient ways to train and/or analyse their technique and fitness to improve their performance. Consequently, laboratory and/or field-based physiological monitoring tools used at regular intervals at key time points throughout the year must be considered to help with training evaluation. Due to the limited availability of specialized

equipment for testing wheelchair-dependent participants in the laboratory, the adoption of field-based testing has become the preferred option by many team coaches of wheelchair athletes. An obvious advantage of field-based testing is that large groups of athletes can be tested in less time. Furthermore, athletes are tested in their natural environment (using their normal sports wheelchair set-up and floor surface), potentially making the results of such testing more relevant than laboratory testing. Careful selection of tests to enable coaches to distinguish between disability classifications, wheelchair proficiency and actual performance improvements is paramount as this will not only enhance the value of field-based testing, but also help with the development of meaningful normative values.

Reference

Goosey-Tolfrey, V.L and Leicht, C.A. (2013). Field based testing of wheelchair athletes. *Sports Medicine*. 43(2):77-91.



PERFORMANCE SPORT

Current perspectives on profiling and enhancing wheelchair court-sport performance

Introduction

Despite the growing interest in Paralympic sport, the evidence-base for supporting elite wheelchair sport performance remains in its infancy compared to able-bodied sport.

Subsequently, current practice is often based on theory adapted from able-bodied guidelines, with a heavy reliance on anecdotal evidence and practitioner experience. Many principles of training prescription and performance monitoring in wheelchair athletes are directly transferable from able-bodied practice, including the periodisation and tapering of athlete loads around competition. Yet, a consideration for the physiological consequences of an athlete's impairment and the interface between the athlete and their equipment are vital when targeting interventions to optimise in-competition performance.

Methods

This review article outlined scientific evidence and current perspectives on profiling and enhancing physical performance in the court sports. Specifically, the focus was on i) laboratory and field based assessments of physical capacity related to court-sport performance; ii) techniques and technologies available for profiling on-court physical performance, and iii) the evidence base for targeted interventions aimed at enhancing physical performance, including training prescription, equipment innovations and thermoregulation.



Main findings and applications

- An understanding of the individual wheelchair athlete is vital, including a full medical diagnosis of physical impairment, screening of current functional movement patterns and previous injury and illness history.
- Profiling protocols must show good reliability and demonstrate specificity to the movement or energetic demands of competition. The battery of protocols available to practitioners will be dependent on available resource (lab vs. field assessments), the experience of athletes being profiled (novice vs. experienced wheelchair user) and contact time available with athletes.
- A range of technologies are available for examining the movement and physiological demands of performance, including heart rate monitoring, motion capture, indoor tracking systems and inertial movement units. However, the limitations of each technique must be acknowledged and considered when supporting coaches in the training and competition environment.
- A multi-disciplinary approach to the preparation and assessment of interventions aimed at enhancing physical performance is essential. Interventions may increase one element of performance (linear speed) but be detrimental to other parameters of athlete health or performance.

Reference

Paulson, T. and Goosey-Tolfrey, V. (2016). Current perspectives on profiling and enhancing wheelchair court-sport performance. *International Journal of Sports Physiology and Performance*. doi: 10.1123/ijsp.2016-0231 [Epub ahead of print].

PERFORMANCE SPORT

Teach your athletes how to breathe – It may be important for wheelchair racing performance

Introduction

In wheelchair racing, respiratory muscles of the rib cage are also involved in non-ventilatory functions – they help stabilise the body and are therefore an important part of the push performance.

The relationship between locomotor-respiratory coupling (the ratio between push and breathing frequency), respiratory parameters and work efficiency is not known in wheelchair athletes. This study aimed to gain further insights into the interplay between respiration and performance.

Methods

8 trained and experienced Wheelchair Racers completed 3 time-trials over the distances of 400, 800 and 5000 m on a roller system. During the time trials, we measured ventilatory and gas exchange variables as well as push frequency.



Image: Claudio Perret

Main findings and applications

- 4 different coupling ratios were identified, namely 1:1 (one push for every breath taken); 2:1, 3:1 as well as a 1:1/2:1 alternating type, respectively.
- The 1:1/2:1 alternating coupling type was found predominantly during the 400 m time-trial. Longer race distances tended to result in an increased coupling ratio (e.g., from 1:1 toward 2:1), and a more efficient respiration was found over the 5000 m distance (“deeper breaths”, resulting in reduced work of breathing).
- These findings suggest that a higher coupling ratio indicates enhanced breathing work efficiency with a concomitant deeper and slower respiration. The selection of an appropriate coupling strategy may help to enhance Wheelchair Racing performance.

Reference

Perret, C., Wenger, M, Leicht, C. and Goosey-Tolfrey, V.L. (2016). Locomotor-respiratory coupling in wheelchair racing athletes: a pilot study. *Frontiers in Physiology*, 7: 11.



Image: Claudio Perret

PERFORMANCE SPORT

Does an abdominal binder improve performance in athletes with tetraplegia?

Introduction

Spinal cord injury (SCI) elicits a lesion-dependent impairment in cardiorespiratory function that may conspire to limit exercise performance.

Abdominal binding improves resting cardiorespiratory function in individuals with cervical SCI. The following studies explored whether elastic binding of the abdomen i) influences respiratory mechanics during wheelchair propulsion and ii) improves field-based measures of fitness in highly-trained individuals with cervical SCI.

Methods

Study 1. 8 Wheelchair Rugby players with motor-complete SCI (C5-C7) performed submaximal and maximal incremental exercise tests on a treadmill, both with and without abdominal binding. Measurements included pulmonary function, pressure-derived indices of respiratory mechanics, operating lung volumes, tidal flow-volume data, gas exchange, blood lactate, and symptoms.

Study 2. 10 Wheelchair Rugby players with traumatic SCI (C5-C7) completed four experimental trials both with and without abdominal binding. Performance was assessed using i) the time taken to complete an agility test and an acceleration/deceleration test; ii) the gross efficiency of wheelchair propulsion and the peak-power/ the propulsion kinematics of a 30 s Wingate test; iii) the fatigue index of a 10 x 20 m repeated push test and iv) the distance covered and the metabolic/ perceptual responses to two maximal 4-min pushes.

Main findings and applications

- Abdominal binding shifts tidal breathing to lower lung volumes without influencing flow limitation, symptoms, or exercise tolerance.
- Changes in respiratory mechanics with binding may benefit oxygen transport capacity through an improvement in central circulatory function.
- Selected measures of field-based fitness were also improved with binding.
- Abdominal binding did not alter push kinematics which suggests that athletes can utilize the benefits of abdominal binding without altering their push technique.

Reference

- West, C., Goosey-Tolfrey, V.L., Campbell, I.G. and Romer, L.M. (2014). Effect of abdominal binding on respiratory mechanics during exercise in athletes with cervical spinal cord injury. *Journal of Applied Physiology*. 117(1): 36-45.
- West, C., Campbell, I.G., Mason, B., Goosey-Tolfrey, V.L. and Romer, L.M. (2014). Effect of an abdominal binder on measures of field-based fitness in Paralympic wheelchair rugby players. *Australian Journal of Science and Medicine in Sport*. 17(4): 351-5.



PERFORMANCE SPORT

Ratings of Perceived Exertion: Differentiated perceived exertion and self-regulated wheelchair exercise

Introduction

Ratings of perceived exertion (RPE) have previously been employed for prescription and self-regulation of exercise intensity across a range of exercise modalities, including treadmill exercise, cycling, arm-cranking, handcycling and wheelchair propulsion.

However, it is recognised that the strength of the perceptual signal is greater from the exercising limbs and joints (peripheral RPE) when compared to central signals of cardio-respiratory strain, such as heart rate and ventilation (central RPE), during submaximal wheelchair propulsion. The prescription and self-regulation of exercise may be enhanced in novice wheelchair users by using an RPE specific to the peripheral exertional signals experienced during hand-rim propulsion.

Methods

18 participants completed a sub-maximal incremental test and a graded test to exhaustion to determine peak oxygen uptake (VO_{2peak}) on a wheelchair ergometer. On a separate day, each participant performed two 12-min intermittent bouts consisting of three 4-min stages at individualised imposed power outputs (PO) equating to 'light' (40% VO_{2peak}) and 'moderate' (60% VO_{2peak}) intensity exercise. On a third occasion, participants were assigned to either the overall group (n=9) or peripheral group (n=9) and were required to self-regulate 12-min intermittent exercise according to either overall or peripheral RPE reported during the corresponding imposed intensity trial.

Main findings and applications

Peripheral RPE provided the dominant perceptual signal during submaximal wheelchair exercise. When self-regulating exercise based on perceptual exertional signals, peripheral RPE enabled a more precise self-regulation of moderate-intensity wheelchair exercise in a novice user group than overall RPE.

In contrast, during light-intensity exercise, overall RPE provided a more accurate self-regulation tool and should be employed prior to familiarisation with differentiated RPE during light-intensity wheelchair propulsion training.

Reference

Paulson, T., Bishop, N., Eston, R. and Goosey-Tolfrey, V. (2013) Differentiated perceived exertion and self-regulated wheelchair exercise. *Archives of Physical Medicine and Rehabilitation*. 94(11): 2269-2276.



PERFORMANCE SPORT

Can you predict peak oxygen uptake from differentiated ratings of perceived exertion in trained wheelchair sportspersons?

Introduction

During periods of high intensity training, it may not be possible for all wheelchair sportspersons to complete a test to volitional exhaustion due to their concerns with the aggravation of a previous injury.

For that reason, predicting VO_{2peak} from submaximal bouts of exercise may be welcomed if a test has to be terminated early. This study therefore assessed the validity of predicting VO_{2peak} from differentiated ratings of perceived exertion (RPE) obtained during submaximal wheelchair propulsion.

Methods

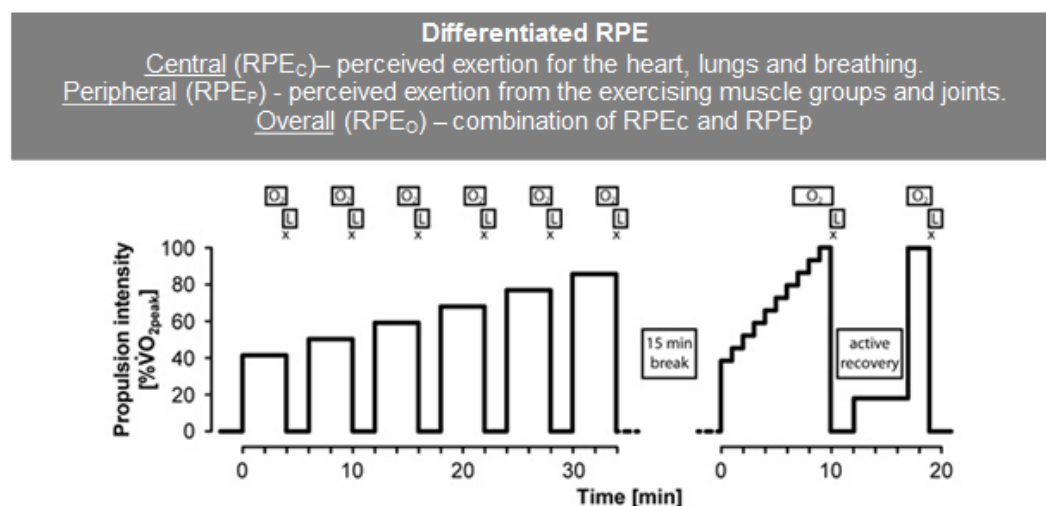
3 sub-groups of elite male wheelchair athletes (9 individuals with tetraplegia (TETRA); 9 with paraplegia (PARA); and 8 athletes without spinal cord injury (NON-SCI)) performed an incremental speed exercise test followed by graded exercise to exhaustion test (VO_{2peak}) on a treadmill.

Main findings and applications

- Differentiated RPE may be used cautiously for TETRA and PARA athletes when predicting VO_{2peak} across the RPE perceptual range of 9 to 15.
- It appears that central RPE and peripheral RPE mediate overall RPE similarly during wheelchair propulsion.
- However, predicting VO_{2peak} using these methods is not recommended for the NON-SCI athletes due to the large coefficients of variation (16.8, 20.2 and 18.0%; RPE_c , RPE_p and RPE_o , respectively).

Reference

Goosey-Tolfrey, V., Paulson, T.A.W, Tolfrey, K. and Eston R.G. (2014). Prediction of peak oxygen uptake from differentiated ratings of perceived exertion during wheelchair propulsion in trained wheelchair sportspersons. *European Journal of Applied Physiology*. 114(6): 1251-1258.



Note. Measurement of: O₂ = oxygen uptake; L = blood lactate; x = differentiated RPE.

BODY COMPOSITION

Comparing methods of estimating body composition in highly trained wheelchair athletes

Introduction

The assessment of body composition in athletes is commonly used as a tool to help define the impact that sports training and dietary interventions have on adipose tissue.

When working with Paralympic athletes the estimation of body composition is problematic because the transferability of able-bodied athletes' normative values are questionable due to the increased fat mass and decreased bone density and lean mass often reported in these individuals. Currently, the methods available to assess adiposity changes in wheelchair athletes have tended to include simple and relatively cheap field-based techniques, such as skinfold callipers and bioelectrical impedance analysis (BIA). However, there are issues with many of these predictions and the physical impairment of the athlete must be carefully considered. Many studies comparing body composition methodologies exist using AB cohorts but there is little evidence to help inform the selection of a methodology for athletes with physical impairments.



Methods

30 wheelchair games players from the sports of Wheelchair Basketball and Rugby (11 athletes with paraplegia and 11 with tetraplegia, 8 athletes with other impairments) participated. Each athlete was assessed using DXA, BIA, sum of 8 skinfolds and air displacement plethysmography (ADP).

Main findings and applications

- Total percentage body fat was $25.0 \pm 6.6\%$.
- No significant difference between SCI levels.
- Athletes with paraplegia had significantly lower fat-free mass and higher fat mass than athletes with other impairments likely due to muscle atrophy below the level of SCI.
- Compared to the DXA, BIA and ADP overestimated fat-free mass and underestimated fat mass. These methods should therefore be used with caution in wheelchair athletes with substantial body asymmetry, lower-body muscular atrophy and upper-body muscular development.
- Predictions of % body fat from skinfold analysis were all underestimated compared to DXA measurements.
- Further validation of predictive models of body composition in wheelchair athletes is warranted.

Reference

Goosey-Tolfrey, V. L., Keil, M., Brooke-Wavell, K. and de Groot, S. (2016). A comparison of methods for the estimation of body composition in highly trained wheelchair games players. *International Journal of Sports Medicine*. 37(10): 799-806.

BODY COMPOSITION

Dual-energy x-ray absorptiometry, skinfold thickness and waist circumference for assessing body composition in ambulant and non-ambulant wheelchair games players

Introduction

Field-based assessments provide a cost-effective and accessible alternative to dual-energy X ray absorptiometry (DXA) for practitioners determining body composition in athletic populations.

It remains unclear how the range of physical impairments classifiable in wheelchair sports may affect the utility of field-based body composition techniques.

Methods

The present study assessed body composition using DXA in 14 wheelchair games players who were either wheelchair dependent (non-walkers; n=7) or relied on a wheelchair for sports participation only (walkers; n=7). Anthropometric measurements were used to predict body fat percentage with existing regression equations established for able-bodied persons by Sloan and Weir, Durnin and Womersley, Lean et al, Gallagher et al and Pongchaiyakul et al. In addition, linear regression analysis was performed to calculate the association between body fat percentage and BMI, waist circumference, and the sum of 6 and 8 skinfold thicknesses.



Main findings and applications

- Non-walkers had significantly lower total lean mass (46.2 ± 6.6 vs. 59.4 ± 8.2 kg, $p=0.006$) and total body mass (65.8 ± 4.2 vs. 79.4 ± 14.9 kg; $p=0.05$) compared to walkers.
- Body fat percentage calculated from most existing regression equations was significantly lower than from DXA, by 2-9% in walkers and 8-14% in non-walkers.
- Of the anthropometric measurements, the sum of 8 skinfold thicknesses had the lowest standard error of estimation in predicting body fat content.
- In conclusion, existing anthropometric equations developed in able-bodied populations substantially underestimated body fat content in wheelchair athletes, particularly non-walkers. Impairment specific equations may be needed in wheelchair athletes.

Reference

Willems, A., Paulson, T. A., Keil, M., Brooke-Wavell, K. and Goosey-Tolfrey, V. L. (2015). Dual-energy X-ray absorptiometry, skinfold thickness, and waist circumference for assessing body composition in ambulant and non-ambulant wheelchair games players. *Frontiers in Physiology*. 6: 356.

BODY COMPOSITION

Dual-energy X-ray absorptiometry (DXA) is a highly reproducible measure of body composition in wheelchair athletes

Introduction

In persons with a physical impairment such as a spinal injury, physiological and metabolic changes occur that both directly and indirectly affect body composition.

Muscle atrophy and a reduction in the cross sectional area of the muscle fibres occur largely as a result of muscle disuse. The assessment of body composition is a useful means of evaluating the effectiveness of nutritional strategies and training interventions designed to impact fat mass and fat-free mass. Determining DXA reproducibility among individuals with disability is necessary due to the vast body composition changes that occur, rendering able-bodied values impractical and without value. The purpose of this study was to determine the reproducibility of body composition measurements by DXA in elite athletes with a physical impairment.



Methods

12 elite male Wheelchair Basketball players (3 complete SCI>T5 / 1 incomplete T9-10 / 4 congenital spinal related injuries / 3 amputees / 1 club foot) participated in this study. Each participant underwent a whole body DXA scan which was repeated on the same day to assess total and regional body composition.

Main findings and applications

- Mean percentage body fat was $26.6 \pm 6.5\%$, which is comparable with previously reported data of highly trained athletes in the UK and worldwide.
- Due to the large range of physical impairments, fat and lean tissue mass varied greatly.
- There were some difficulties in positioning athletes due to scoliosis, curvature of the spine, inability to extend the knee, absence or abnormal anatomy of the lower limb landmarks.
- DXA proved to be a highly reproducible measure of total and regional body composition of elite Wheelchair Basketball athletes.
- DXA can detect individual changes in fat mass of at least 1 kg, lean tissue mass of 1.1 kg and bone mineral content of 0.12 kg.

Reference

Keil, M., Brooke-Wavell, K., Totoly de Zepetnek, J. and Goosey-Tolfrey, V.L. (2016). Measurement precision of body composition variables in elite wheelchair athletes, using dual-energy x-ray absorptiometry. *European Journal of Sport Sciences*. 16(1): 65-71.

NUTRITIONAL SUPPLEMENTS

Nutritional supplement use is common among athletes with a physical impairment

Introduction

It is widely accepted that nutrition can influence exercise performance and that it should be integrated into an athlete's programme to fully capitalise on their athletic potential.

Likewise, the use of some nutritional supplements (NS) may also have the ability to improve sporting performance. It is therefore unsurprising that the consumption of NS is common among able-bodied athletes (~50-80%) yet we currently do not understand the NS practices of athletes with an impairment.

Methods

The questionnaire included; i) 12 closed and 9 open-ended; ii) 10 multiple-choice; iii) 7 Likert-type rating scale; and iv) 2 ranking questions. The questionnaire captured data pertaining to individual characteristics, NS habits, reasons for NS use/ non-use and sources of information. A copy of the questionnaire can be found here: <http://www.lboro.ac.uk/research/phc/resources/resources/> and was made available in English, French, German, Portuguese and Spanish.

A total of 399 athletes (74% male, 26% female) across 5 impairment categories (42% spinal cord injury, 19% amputation, 18% Les Autres, 11% cerebral palsy and 10% visual impairment), 28 sports and 21 Nationalities completed the questionnaire.



Main findings and applications

- 58% of athletes reported the use of NS in the previous 6 months.
- Most used NS were similar to able-bodied athletes; protein, sports drinks, multivitamins and carbohydrate providing NS. As were their top reasons for use; recovery, immunity, and energy.
- 41% of athletes followed the able-bodied recommendations on the NS label, which may be linked to the 9% that experienced negative side-effects following their use.
- Elite athletes were 1.6 times more likely to use NS than those at a lower level, which is likely linked to longer training hours and/or access to a nutritionist/ dietitian.
- 52% of athletes indicated that they would like more information/education on NS.
- Top 3 sources of information on NS were sports nutritionist/dietitian, coach and training partner/athlete. Hence, impairment-specific NS information should be delivered on coaching courses, and sports nutritionists/dietitians should be upskilled to deliver NS education to athletes themselves.

Reference

Graham-Paulson, T.S., Perret, C., Smith, B., Crosland, J. and Goosey-Tolfrey, V.L. (2015). Nutritional supplement habits of athletes with an impairment and their sources of information. *International Journal of Sport Nutrition and Exercise Metabolism*. 25(4): 387-395.

Thank you to The World Anti-Doping Agency for helping to fund this project through a Social Science Research Grant. The final report can be seen here: www.wada-ama.org/en/resources/social-science/nutritional-supplement-habits-and-perceptions-of-athletes-with-a-disability

NUTRITIONAL SUPPLEMENTS

Caffeine improves preloaded cycling but not handcycling 10 km time trial performance

Introduction

Low-moderate doses of caffeine (3–6 mg•kg⁻¹) have been shown to positively influence cycling time-trial (TT) performance in able-bodied individuals. During cycling, the leg musculature is the main force producer.

It is debatable whether the findings from such cycling studies are transferable to upper-body exercise (UBE) sports such as kayaking, handcycling and wheelchair sports where the arms produce this force. Caffeine influences the central nervous system by which it acts as an adenosine receptor antagonist to produce motor-activating and arousing effects. With this mechanism in mind, a similar ergogenic benefit could be expected during UBE yet the evidence remains equivocal.

Methods

11 recreationally active males (age 24±4 y, body mass 85.1±14.6 kg, lower and upper-body VO_{2peak} 42.9±7.3 and 27.6±5.1 mL•kg•min⁻¹) participated. Participants attended the laboratory on 8 separate occasions, which consisted of a VO_{2peak} test, a familiarization and 2 (4 mg•kg⁻¹ caffeine and placebo) experimental trials for both cycling and handcycling. The experimental trials consisted of a preload at 65% mode-specific VO_{2peak}, 5 min recovery and a 10 km TT.



Main findings and applications

- Caffeine improved preloaded cycling TT performance (2.1%; p=0.033), which was seen as an increased power output during the first and last 2 km. However, caffeine failed to significantly improve handcycling performance (1.8%; p=0.153).
- Participants with a UBE VO_{2peak} greater than the mean value (27.6 mL•kg•min⁻¹) improved their handcycling TT performance by 3.2% whereas those below the mean had a 0.3% reduction. Hence, training status may help to explain the inter-individual variability reported in this study.
- Caffeine resulted in greater blood lactate concentrations post-TT, which is common in the literature, especially in conjunction with improved performance.
- Caffeine reduced ratings of perceived exertion during constant rate cycling and handcycling but this effect was diminished during the high-intensity TT.
- The lack of performance improvement during the handcycling TT may be linked to a smaller proportion of type I muscle fibres in the arms compared to the legs in non-specifically UBE-trained participants. It has also been suggested that type II muscle fibres are less sensitive to caffeine.

Reference

Graham-Paulson, T.S., Perret, C. and Goosey-Tolfrey, V.L. (2016). Improvements in cycling but not handcycling 10 km time trial performance in habitual caffeine users. *Nutrients*. 8(7): E393.

NUTRITIONAL SUPPLEMENTS

Caffeine improves 20 m sprint and a one-off 4-min push performance in Wheelchair Rugby players

Introduction

Caffeine can be beneficial during short-term, endurance and repeated sprint (running) performance.

However, little evidence exists regarding its effects during upper-body exercise and in individuals with a physical impairment. Wheelchair sports such as Rugby, Basketball and Tennis are intermittent in nature and require short bursts of high intensity movements superimposed on a background of aerobic activity. The current study therefore used wheelchair sport field tests to assess the impact of caffeine on both sprint and short-term endurance performance.

Methods

12 male club-level Wheelchair Rugby players (age 30.0 ± 7.7 y, body mass 69.6 ± 15.3 kg and training hours 11.1 ± 3.5 h \cdot wk $^{-1}$), participated. 7 participants had a cervical level SCI.

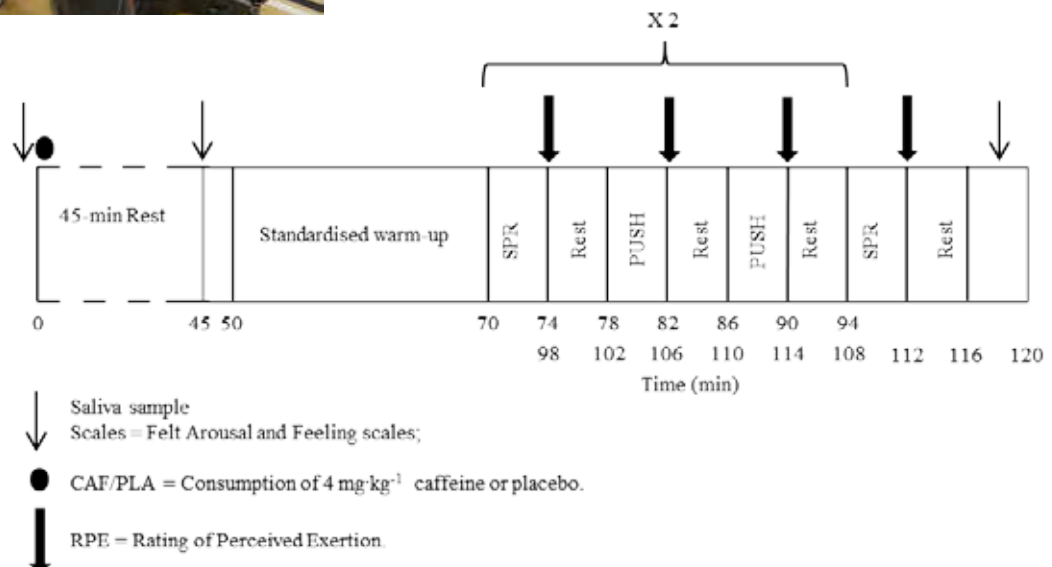


Main findings and applications

- Average 20 m sprint (SPR) times were significantly faster following caffeine during SPR1 and SPR2 ($p=0.037$ and 0.016 , respectively). Total SPR time was also significantly faster during caffeine compared to placebo ($p=0.006$).
- Participants covered more distance during the first 4-min PUSH following caffeine ($p=0.047$) but this ergogenic effect diminished thereafter, indicating that caffeine may impact upon a one-off effort but not repeated bouts.
- Felt arousal and ratings of perceived exertion did not differ between trials.
- Caffeine increased Feeling scores which may have contributed to improved performance.
- Side-effects were reported by 5 participants, which may indicate that individuals with a physical impairment should initially trial lower doses ($1-3$ mg \cdot kg $^{-1}$).

Reference

Graham-Paulson, T.S., Perret, C., Watson, P. and Goosey-Tolfrey, V.L. (2015). Improvement in sprint performance in wheelchair sportsmen with caffeine supplementation. *International Journal of Sport Physiology and Performance*. 11(2): 214-220.



NUTRITIONAL SUPPLEMENTS

Individuals with a spinal cord injury display large inter-individual variation in caffeine absorption

Introduction

Great inter-individual variability in wheelchair performance responses have been reported during a 1500 m time trial (Flueck et al., 2014), 4-min maximal push and repeated 20 m sprints following caffeine (Graham-Paulson et al., 2015), especially in individuals with a spinal cord injury (SCI).

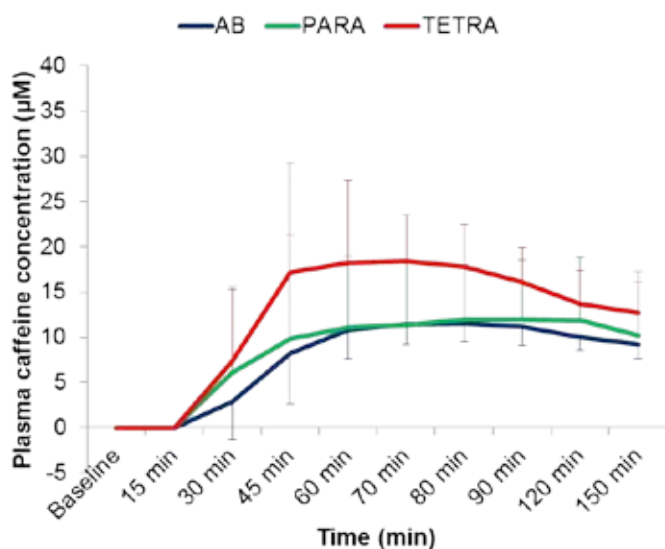
The authors highlighted the potential for slower caffeine absorption due to delayed gastrointestinal transit times and prolonged gastric emptying, especially in those with a cervical lesion level (Kao et al., 1999). Both metabolic and physiological functions are altered in individuals with a SCI, and the level and completeness of injury has been shown to influence drug pharmacokinetics. There is therefore reason to believe that caffeine absorption may also be delayed in persons with a SCI.

Methods

24 healthy males (8 able-bodied, 8 individuals with paraplegia (PARA) and 8 with tetraplegia (TETRA)) consumed 3 mg•kg⁻¹ caffeine in a fasted state. Plasma caffeine [CAF], glucose, lactate, free-fatty acid [FFA] and catecholamine concentrations were measured during a 150 min rest period.

Main findings and applications

- Different patterns of absorption were evident between groups (see figure).
- Greater peak [CAF] was observed in TETRA, which may reflect slow metabolism and renal clearance due to impaired liver and kidney function following SCI. A reduced blood volume may also result in a falsely large peak.
- Large inter-individual variance was seen in both SCI groups which likely reflects the heterogeneity of this population regarding level and completeness of SCI.
- Increased [FFA] despite no significant increase in catecholamine concentrations indicates a direct effect of caffeine on adipocytes.
- Low catecholamine concentrations support previous data and reflect impaired sympathetic activation of the nervous system in TETRA.
- There were no differences between groups' blood glucose or lactate concentrations.
- For short-term exercise caffeine should be consumed 70-80 min prior to performance.
- TETRA may consider using a lower dose to elicit similar [CAF] to able-bodied individuals but it remains to be investigated whether this is ergogenic.



Reference

Graham-Paulson, T.S., Paulson, T.A.W., Perret, C., Tolfrey, K., Cordery, P. and Goosey-Tolfrey, V.L. (2016). Spinal cord injury level influences acute plasma caffeine responses. *Medicine and Science in Sports and Exercise*. *Medicine and Science in Sports and Exercise*. 49(2): 363-370.

PERFORMANCE HEALTH

Future Work: Using perceived exertion to regulate exercise intensity during upper-body exercise

Introduction

Traditionally exercise is prescribed and regulated using objective markers of exercise intensity, such as heart rate and power output. However, it is possible that within both exercise testing and exercise prescription settings, regulating intensity using subjective ratings of perceived exertion (RPE) may also be applicable.

For exercise testing using a protocol based on progressively increasing RPE over the course of a test, rather than power output, will make tests of fixed, rather than open-ended in terms of duration. It would also afford the participant control over pacing.

With regards to exercise prescription, using RPE provides an inexpensive and easy to implement means of regulating exercise intensity. Self-regulating exercise intensity has also been shown to be more enjoyable, a factor that helps predict future levels of physical activity.

Aims and objectives

- To investigate the validity and reliability of a self-regulated exercise test to measure maximal physiological responses during upper-body exercise.
- To assess whether RPE can be used as a valid and reliable means to regulate exercise intensity during continuous and interval-based exercise sessions.

Why is this important?

Other work at the PHC is working towards the development of specific physical activity guidelines for people with a spinal cord injury. A key component of any exercise intervention is the intensity. Regulating exercise intensity accurately is complex and often requires expensive equipment when performed outside the laboratory. If RPE is shown to be a valid and reliable measure then it would help simplify messages regarding intensity regulation and therefore feed into the physical activity guidelines.



PERFORMANCE HEALTH

Spinal cord injury level and the circulating cytokine response to strenuous exercise

Introduction

The effect of the resulting decreased sympathetic outflow in individuals with tetraplegia includes depressed circulating adrenaline and noradrenaline plasma concentrations at rest, during and after exercise.

If the sympathetic nervous system (SNS) only plays a minor role in the IL-6 (an inflammation mediating cytokine) response to exercise, then individuals with complete injuries above T6 would be expected to demonstrate similar elevations in circulating IL-6 concentrations after exercise to those observed in individuals with an intact SNS (i.e. who are injured at or below T6, or who do not have a SCI). However, if this is not the case, a limited IL-6 response in those with injuries above T6 could have important health implications given the proposed metabolic and inflammatory roles of muscle-derived IL-6 in a population with already limited physical capacity.

Methods

26 elite male wheelchair athletes (8 individuals with C6-C7 tetraplegia (TETRA); 10 with T6-L1 paraplegia (PARA); and 8 non-spinal cord injured controls (NON-SCI)) performed a submaximal exercise test followed by a graded exercise to exhaustion test on a motorised treadmill. Blood samples were taken pre-exercise, post-exercise and 30 min post-exercise (post30) and analysed for concentrations of IL-6, IL-10, IL-1 receptor-antagonist (IL-1ra), tumor necrosis factor-alpha (TNF- α), adrenaline and cortisol.

Main findings and applications

- This study suggests the SNS plays an important regulatory role in the circulating IL-6 response to exercise.
- Our findings support a role for the SNS as an important modulator of the release and/or synthesis of IL-6 from contracting skeletal muscle.
- This has important health implications for individuals with a cervical SCI as exercise-induced elevations in plasma IL-6 have previously been related to the creation of an anti-inflammatory environment in the hours post-exercise. This in turn has been associated with a reduction in the risk of developing cardiovascular disease, a major cause of mortality in those with a SCI.

Reference

Paulson, T., Goosey-Tolfrey, V., Lenton, J., Leicht, C. and Bishop, N. (2013). Spinal cord injury level and the circulating cytokine response to strenuous exercise. *Medicine and Science in Sports and Exercise*. 45(9): 1649-1655.



PERFORMANCE HEALTH

Inflammation-mediating cytokine response to acute handcycling exercise with/without functional electrical stimulation (FES)-evoked lower limb cycling

Introduction

Lower-limb paralysis and immobilisation following a spinal cord injury (SCI) predispose individuals to an elevation in cardiovascular disease risk factors; including chronic inflammation.

Participation in regular exercise can reduce cardiovascular disease risk, in part because exercise may exert a down-regulatory effect on inflammatory pathways driving the development of insulin resistance and atherosclerosis. This study investigated whether the inflammation-mediating potential of handcycling exercise can be enhanced by the addition of concurrent electrical stimulation-evoked lower-limb cycling.

Methods

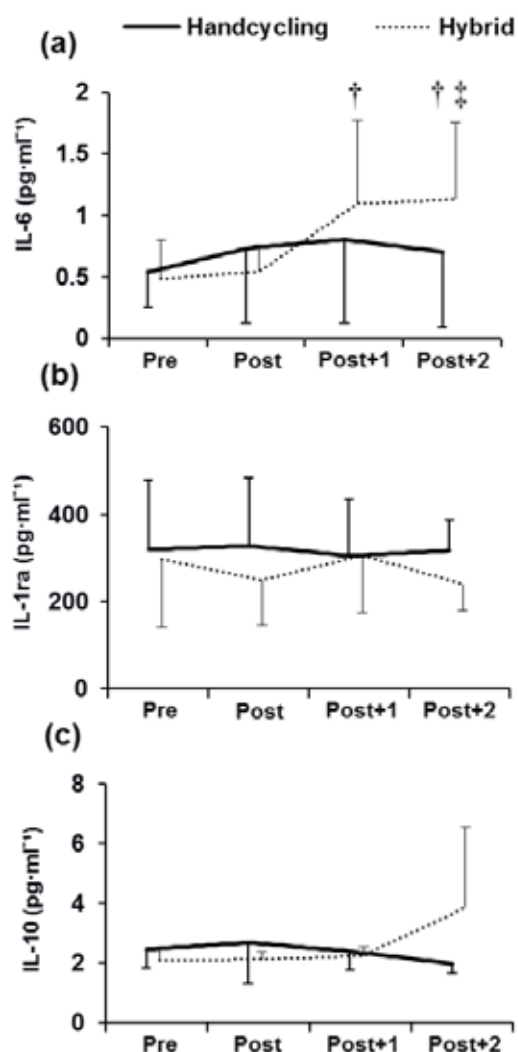
On two separate occasions, 5 recreationally active, community-based participants with motor complete paraplegia (T5-7) performed 30 min handcycling and hybrid exercise (HYB) at a fixed power output. Venous blood samples were collected at rest, immediately post-exercise, 1 h (post+1) and 2 h post-exercise (post+2). Plasma interleukin-6 (IL-6), IL-10, IL-1ra, adrenaline and cortisol concentrations were determined via enzyme-linked immunoassay.

Main findings and applications

- Initial findings suggest paralysed skeletal muscle releases the myokine IL-6 in response to electrically evoked contractions. Moderate intensity (60% power output (PO_{peak}) obtained during handcycling only) hybrid exercise was associated with an elevation in plasma concentrations of the anti-inflammatory cytokine IL-10; an effect not present when performing handcycling exercise alone in an untrained cohort.
- Hybrid exercise may offer a method of maximising the anti-inflammatory potential of acute exercise in individuals with a thoracic SCI responsive to FES-evoked contractions.
- When performing voluntary upper-limb exercise alone, the absolute exercise intensity (W), as well as the relative exercise intensity (% PO_{peak}), may be important in determining the magnitude of the anti-inflammatory cytokine response.

Reference

Paulson, T., Bishop, N., Smith, B. and Goosey-Tolfrey, V. (2014). Inflammation-mediating cytokine response to acute handcycling exercise with/without functional electrical stimulation-evoked lower limb cycling. *Journal of Rehabilitation Research and Development*. 51(4): 645-654.



PERFORMANCE HEALTH

Effects of hybrid cycle and handcycle exercise on cardiovascular disease risk factors in persons with a spinal cord injury: A randomised controlled trial

Introduction

Participation in regular exercise has been shown to promote a range of anti-inflammatory benefits in non-disabled individuals, including reduced visceral adiposity.

However, in SCI, the anti-inflammatory benefits of exercise may be lower due to lower-limb paralysis, and reliance on the relatively small muscle mass activated during upper-body activities such as handcycling. To date, no intervention studies have examined the effect of long-term upper-body exercise on chronic inflammation in persons with a SCI. The activation of the paralysed lower-limb musculature via functional electrical stimulation (FES)-evoked cycle training has previously been shown to significantly reduce plasma concentrations of the inflammatory mediators CRP, IL-6 and tumour necrosis factor-alpha. The performance of combined FES-evoked leg exercise and voluntary upper-body exercise (i.e. hybrid exercise) has the potential to augment the anti-inflammatory response even further, since a larger muscle mass is activated than during FES-evoked leg exercise or upper-body exercise alone.

Methods

Multicentre randomized controlled trial. Both the hybrid cycle group (n=9) and the handcycle group (n=10) trained twice a week for 16 weeks. Outcome measures obtained pre and post the programme were: metabolic syndrome components (waist circumference, systolic and diastolic blood pressure, high-density lipoprotein cholesterol, triglycerides and insulin resistance), inflammatory status (C-reactive protein (CRP), interleukin (IL)-6 and -10), and visceral adiposity (trunk and android fat).

Main findings and applications

- Significant reductions were found for waist circumference (p=0.001), diastolic blood pressure (p=0.03), insulin resistance (p=0.006), CRP (p = 0.05), IL-6 (p=0.04), IL-6/IL-10 ratio (p=0.03), and trunk (p=0.04) and android (p=0.02) fat percentage.
- The 16-week exercise programme, using either a hybrid cycle or a handcycle, found similar beneficial effects on metabolic syndrome components, inflammatory status and visceral adiposity, indicating that there were no additional benefits of FES-induced leg exercise over handcycle exercise alone.

- In conclusion, this study demonstrated that a 16-week exercise programme, using either a hybrid cycle or a handcycle had similar beneficial effects on several CVD risk factors, including metabolic syndrome components, inflammatory status and visceral adiposity, indicating that there were no notable benefits of the FES-induced leg exercise over handcycle training alone.

Reference

Bakkum, A., Paulson, T., Bishop, N., Goosey-Tolfrey, V. et al. (2015). Effects of hybrid cycle and handcycle exercise on cardiovascular disease risk factors in people with spinal cord injury: A randomized controlled trial. *Journal of Rehabilitation Medicine*. 47(6): 523-530.



PERFORMANCE HEALTH

Plasma cytokine and exertional responses in relation to exercise intensity and volume of exercising muscle mass during arm-crank ergometry

Introduction

The smaller muscle cross-sectional area of the upper versus lower limb may act to augment intracellular signalling for IL-6 release per unit of contracting muscle when performing a given workload.

It is of interest, therefore, whether the upper limb may initiate an inflammation-mediating cytokine response at lower absolute and relative intensities than observed during lower limb exercise.

Methods

12 recreationally active but upper-limb untrained males performed 30 min: i) low intensity (40% VO_{2peak}) arm crank ergometry (ACE) (LOW); ii) moderate intensity (60% VO_{2peak}) ACE (MOD); and iii) concurrent low intensity (40% VO_{2peak}) ACE plus lower limb cycle ergometry to match total power output in MOD (HYBRID). Plasma concentrations of IL-6, IL-10, IL-1ra, adrenaline and cortisol were determined at rest, immediately post-exercise, and 1 h and 2 h post-exercise. Heart rate (HR) and differentiated ratings of perceived exertion (RPE) were also recorded. This novel study aimed to further scientific knowledge supporting the prescription of regular physical activity and exercise involving the upper limb.

Main findings and applications

- The major finding was that 30 min moderate but not low intensity ACE resulted in an IL-6 response associated with subsequent elevation in plasma concentrations of the anti-inflammatory cytokine IL-1ra. This response occurred independent of sympathetic nervous system activation and at a lower absolute power output than previously observed during lower-limb exercise.
- The absence of an additional plasma IL-6 response following HYBRID versus low intensity ACE alone suggests a greater intracellular signalling for IL-6 in the upper-limb performing an equivalent workload.
- Differentiated RPE were higher for moderate versus low intensity ACE. Hence, a longer duration of low intensity exercise may achieve a greater inflammation-mediating cytokine response while managing peripheral strain in untrained individuals.

- Further longitudinal research is required to maximise the anti-inflammatory potential of regular exercise employing the upper-limb via manipulations in the intensity and/or duration prescribed.

Reference

Paulson, T., Goosey-Tolfrey, V., Leicht, C. and Bishop, N. (2015). Plasma cytokine and exertional responses in relation to exercise intensity and volume of exercising muscle mass during arm-crank ergometry. *Applied Physiology, Nutrition and Metabolism*. 40(8): 782-787.



PERFORMANCE HEALTH

Arm exercise is as effective as leg exercise in eliciting an immune response

Introduction

Exercise can stimulate the immune system by muscles secreting stimulating inflammatory substances.

This response could in theory be reduced when working with a small muscle mass, and the protective effects of exercise against cardiovascular disease and type II diabetes could therefore be compromised. This may particularly affect those restricted to upper body exercise. The purpose of this study was to compare the inflammatory responses for arm exercise and intensity-matched leg exercise.

Methods

12 males performed 45 min constant load exercise trials which were matched for relative intensity (60% of maximum capacity) in either the cycling or the arm cranking modality (these were perceived as equally hard). In addition, they performed a cycling trial at the same absolute intensity as the arm cranking modality (this was perceived as a lot easier because the muscle mass to produce the same amount of work is greater in the legs than the arms).

Main findings and applications

Arm exercise and cycling at the same relative exercise intensity induced a comparable inflammatory response; however, cycling at the same absolute intensity as arm exercise results in a blunted inflammatory response in plasma and blood cell markers.

The adrenaline response was reduced for easy cycling, indicating a smaller exercise stress. Relative exercise intensity appears to be more important to the acute inflammatory response than exercise modality, which is of major relevance for populations restricted to upper body exercise: it means arm exercise is as effective at eliciting an inflammatory response as leg (cycling) exercise.

Reference

Leicht C.A., Paulson T., Goosey-Tolfrey V.L. and Bishop N.C. (2016). Arm and intensity-matched leg exercise induce similar inflammatory responses. *Medicine and Science in Sports and Exercise*. 48(6): 1161-8.



PERFORMANCE HEALTH

Taking a hot bath can induce some of the positive immune changes seen during exercise – extra benefits for individuals with tetraplegia

Introduction

The dysfunctional sympathetic nervous system in individuals with tetraplegia impairs the adrenaline response, and may therefore contribute to the blunted post-exercise inflammatory response.

This may limit the beneficial health effects of exercise. The purpose of this study was to investigate an alternative to exercise to induce an inflammatory response by passively elevating core temperature in individuals with tetraplegia.

Methods

7 males with a motor complete cervical spinal cord injury and 8 able-bodied male controls were immersed for 60 min in water set at a temperature 2-°C above the individuals' resting core temperature (~39-°C).

Main findings and applications

Passive elevation of core temperature acutely elevated a range of inflammatory markers (IL-6, IL-8 and IL-1ra) in tetraplegia despite a blunted adrenaline response. This is in contrast to earlier exercise interventions.

The present study lays the foundation for future studies to explore water immersion as an alternative to exercise to induce an acute inflammatory response in tetraplegia which may help prevent chronic disease (cardiovascular disease or type II diabetes).

Reference

Leicht C.A., Kouda K., Umemoto Y, Banno M., Kinoshita T., Moriki T., Nakamura T., Bishop N.C., Goosey-Tolfrey V.L. and Tajima F. (2015). Hot water immersion induces an acute cytokine response in cervical spinal cord injury. *European Journal of Applied Physiology*. 115(11): 2243-2252.



PERFORMANCE HEALTH

The role of muscle mass and body temperature in the inflammatory response to upper-body exercise and heat

Introduction

Chronic low-grade inflammation is associated with a range of chronic diseases, such as type 2 diabetes and cardiovascular disease.

This state is characterised by elevated resting levels of certain immune cells, like interleukin-6 and the inflammatory monocyte subtype. Regular exercise of sufficient volume can downregulate these levels, which is possibly one of the mechanisms in which exercise has a protective effect against the aforementioned diseases.

Although chronic low-grade inflammation is increasingly prevalent in the general population, possibly due to physical inactivity and diet composition, some populations are at an increased risk for this state (e.g. individuals with a spinal cord injury and the elderly); partly because their physical capacity does often not allow them to perform exercise of sufficient intensity to combat low-grade inflammation. This project investigates alternatives to do so in these at-risk populations. In addition, the mechanisms underlying the effectiveness of these alternatives will be studied, with a focus on the role of body temperature and active muscle mass.



Completed and ongoing research

The first study of this project showed that continuous moderate intensity arm-cranking and an interval protocol with 1 minute high intensity efforts interspersed with 1 minute active recovery are evenly effective in provoking a positive inflammatory response. Since this response to exercise is believed to be influenced by the increase in body temperature, passive heating could also induce part of this response. To investigate this, a project on the potential of hot water immersion to prevent or fight low-grade inflammation is currently underway. Lastly, the role of autonomic function and spinal lesion level in the inflammatory response will be studied with data collected during a wheelchair half-marathon in Oita (Japan).

Future work

The last part of this PhD-project will focus on the mechanisms underlying the inflammatory response to the health promoting strategies described in the previous section. In-vitro methods will be used to explore the effect of different temperatures and exercise responses in populations with distinct characteristics will be studied to gain more understanding into the role of muscle mass and training status. The accumulated knowledge of this project can later be used to inform future work to increase the effectiveness of health promoting strategies for individuals with a low physical capacity.

PERFORMANCE HEALTH

Physiology and biomechanics of forwards and reverse wheelchair propulsion

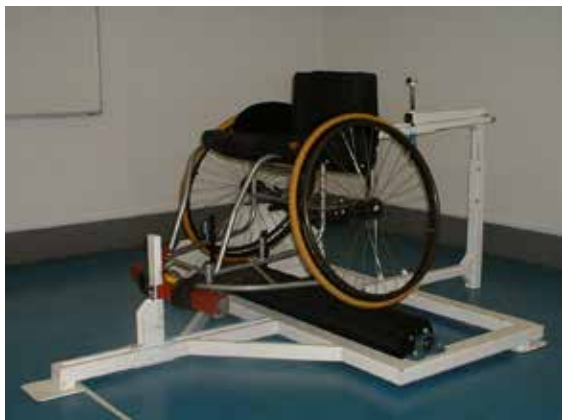
Introduction

Wheelchair mobility during the court sports can be considered multidirectional with lots of braking and sharp changes of direction performed.

The majority of the movements performed are in a forwards direction, however reverse wheelchair propulsion is a skill that accounts for some of the total movements performed, which will utilise different muscle groups to do so. Despite this the effects of reverse wheelchair propulsion are not well known. This study aimed to establish the physiological and biomechanical differences between forwards and reverse propulsion during steady state activities.

Methods

14 able-bodied participants with previous wheelchair propulsion experience pushed a sports wheelchair on a roller ergometer (WERG) in a forwards (FOR) and reverse (REV) direction at 3 sub maximal speeds (4, 6 and 8 km•h⁻¹) for 3 minutes. During the final minute of each trial physiological (oxygen uptake and heart rate) and biomechanical (force application) measures were collected.



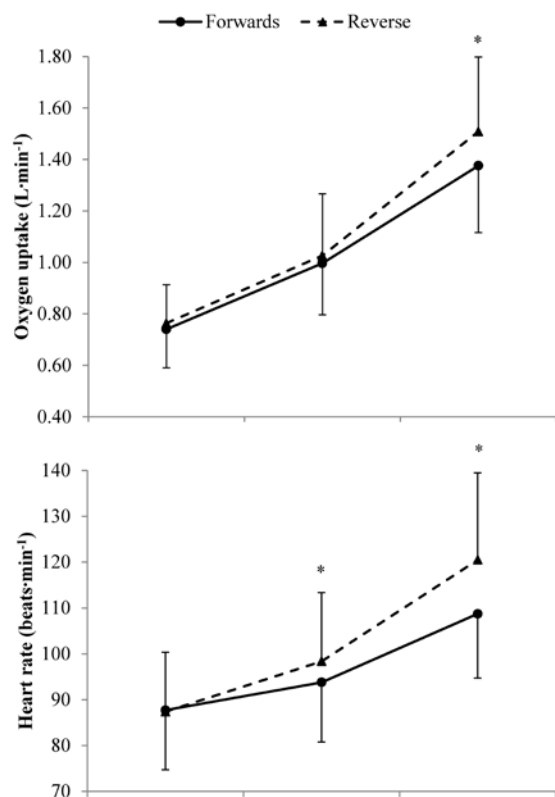
Differences in physiological response between FOR and REV at different speeds (right) and illustration of a sports wheelchair attached to the WERG (above).

Main findings and applications

- Physiological responses were only significantly elevated in REV during the highest speed of propulsion.
- Insufficient force was capable of being applied during REV due to the fact that wheelchairs are configured to optimise forwards propulsion.

Reference

Mason, B. S., Lenton, J. P. and Goosey-Tolfrey, V. L. (2015). The physiological and biomechanical effects of forwards and reverse sports wheelchair propulsion. *Journal of Spinal Cord Medicine*. 38(4): 476-484.



PERFORMANCE HEALTH

Efficiency of hand-rim wheelchair propulsion: Synchronous vs. asynchronous push strategies

Introduction

Wheelchair propulsion is relatively inefficient physiologically in comparison to other forms of locomotion such as running, cycling and handcycling.

Except for handcycling, these modalities tend to be asynchronous (ASY) in their nature prompting the question as to whether wheelchair propulsion could be better if also performed asynchronously. In light of the interests from wheelchair sports and daily wheelchair users which are beginning to utilise an ASY movement pattern makes investigation of such a technique appropriate. Therefore, these studies explored whether an ASY propulsion mode can be more efficient than a synchronous (SYN) propulsion mode.

Methods

To help answer this question, a number of experimental studies compared SYN and ASY propulsion modes in wheelchair games players and novice able-bodied participants. Gross mechanical efficiency (GE) measures, physiological variables, psycho-physiological markers (RPE), propulsion practice and kinetic measures were measured to help address the research question during wheelchair propulsion on a wheelchair ergometer. The overall hypothesis was that 'ASY propulsion will improve the GE of wheelchair propulsion and be more advantageous compared to that of the traditional SYN propulsion'.



Main findings and implications

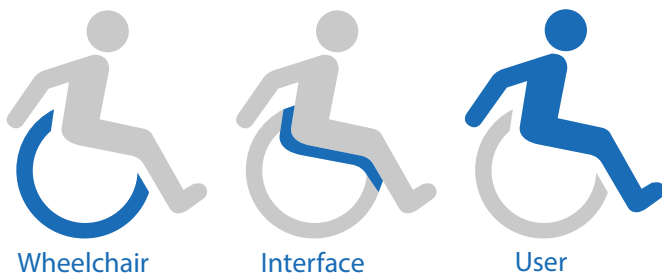
- Push (arm) frequency is the predominant component of push strategy selection for individuals during hand-rim wheelchair propulsion.
- Practice is a key element in improving GE and is particularly advantageous at unpaced freely chosen frequency (FCF) and paced (80% of FCF).
- The feedback mechanism of pacing via the use of audio cues can assist with the practice and learning of the complex task of hand-rim wheelchair propulsion. This would assist the process by encouraging individuals to meet requirements for a more optimum GE.
- Awareness of the rate of rise in hand-rim forces during different push strategies and the possible link with risk of injury.
- Propulsion practice should not be aimed at the optimisation of propulsion force because this may be less efficient and more straining for individuals.
- Push strategy choices can reduce physiological demands and changes to push strategy are easy to manipulate and implement.

Reference

- Lenton, J.P., Fowler, N.E., Woude, van der L.H.V., Nicholson, G., Tolfrey, K. and Goosey-Tolfrey, V.L. (2013). Synchronous hand-rim propulsion forces and efficiency. *International Journal of Sports Medicine*. 34(2):158-164.
- Lenton, J.P., Fowler, N.E., Tolfrey, K., Woude, van der L.H.V. and Goosey-Tolfrey, V.L. (2014). Hand-rim forces in asynchronous and synchronous wheelchair propulsion: a comparison. *International Journal of Sports Medicine*. 35(3):223-231.

PERFORMANCE HEALTH

Posture and Mobility Group (PMG) Project



Introduction

In 2015, the PHC received funding from the Posture and Mobility Group to complete an exploratory study exploring scapula kinematics and shoulder girdle forces during manual wheelchair propulsion.

This work involved an international, multi-disciplinary team of experts and has established methods to enable future work understanding how wheelchair configurations can be manipulated to prevent shoulder girdle pain and improve propulsive efficiency.

Subsequently, the PHC organised a patient and public engagement workshop with the support of the NCSEM and Higher Education Institute (HEI) challenge to explore how outcomes of the exploratory research could be implemented to support current practices around manual wheelchair configuration and shoulder health.



PERFORMANCE HEALTH

Understanding propulsive shoulder forces and scapular kinematics during manual wheelchair use

Introduction

Shoulder pain and inefficient propulsion are common and disabling problems for wheelchair users.

However, little is known about how the interaction between wheelchair configuration and users affects shoulder girdle biomechanics. This can impact significantly on performance during activities of daily living (ADL) and sport. The aim was to establish a feasible and reliable method that could be employed to better understand how manipulating wheelchair configuration can minimise future shoulder girdle pain and pathology.

Methods

10 active males, reliant on a manual wheelchair for both ADL and sport (n=5 with shoulder pain, of which n= 3 unilateral). Each participant performed six 4-min submaximal bouts (3, 4 and 6 km.h⁻¹ (T1), repeated following a 20 min rest (T2)) in their personal ADL wheelchair mounted on a wheelchair ergometer. An instrumented measurement wheel examined propulsion kinetics and technique parameters while three-dimensional kinematic analysis was used to assess bilateral scapulothoracic rotations (internal/external and upward/downward, anterior/posterior tilt) over propulsive cycles.



Figure 1. Participant preparation and placement of EMG and passive motion-capture markers

Dr Tom Paulson won an award for Best Presentation at the Posture and Mobility conference, 2016.

Main findings and applications

- Push frequency, peak force, contact angle, cycle time and power output were all significantly different between each propulsion speed ($p < 0.05$; Effect size=0.38-0.98).
- Common to all speeds was an internally rotated and anteriorly tilted scapula.
- Peak internal rotation of the scapula occurred during the recovery phase of the propulsion cycle and the scapula moved towards a neutral or posteriorly tilted position at ~50% propulsion cycle.
- Mean (~3°) and peak (~4°) scapular internal rotations were significantly greater at 6 km.h⁻¹ than either of the slower speeds. Intra-investigator reliability for the scapular kinematics was: TE=1.6 to 3.1°; ICC=0.87-0.97.
- Absolute bilateral asymmetries ranged from 0.5°-16.7°, 0.4°-11.6° and 0.9°-10.7° for internal, upward rotation and anterior/posterior tilt, respectively.
- Large intra-individual variability was present for bilateral asymmetry with no association between scapular kinematics and self-reported pain symptoms.

Future work

This work has established methods and generated an initial database to enable future work understanding how wheelchair configurations can be manipulated to prevent shoulder girdle pain and improve propulsive efficiency. Furthermore we have developed a robust measurement protocol which can be refined to generate real time information assessing the effectiveness of future wheelchair configuration interventions.

Reference

Dr Tom Paulson, Dr Dylan Morrissey (Queen Mary University of London), Dr Barry Mason, Dr Riemer Vegter (University of Groningen), Dr Bertrand Bru (Charnwood Dynamics Ltd, Codamotion), Prof. Lucas van der Woude (University of Groningen) and Prof. Victoria Goosey-Tolfrey

PERFORMANCE HEALTH

Changes in physiology and technique during different modes of wheelchair propulsion

Introduction

Laboratory-based testing is a popular means for conducting research due to the controlled environment it creates for researchers.

However, in order to maximise the ecological validity, research investigations under laboratory conditions should replicate those of everyday life as closely as possible. For manual wheelchair propulsion this requires a realistic assessment of over-ground wheelchair propulsion. The aim of the current study was to compare the physiological and biomechanical differences between various modes and settings of laboratory-based means for assessing wheelchair propulsion in relation to over-ground propulsion, and to identify an optimal mode for this purpose.

Methods

15 able-bodied participants experienced with wheelchair propulsion performed a 3-minute bout of exercise at 3 fixed speeds (4, 6 and 8 km•h⁻¹) during i) over-ground propulsion on an indoor basketball court; ii) on a roller wheelchair ergometer (WERG); and iii) on a motor driven treadmill at 4 different gradients (0, 0.7, 1.0 and 1.3%). During each bout, heart rate and oxygen uptake was monitored to determine physiological cost and an instrumented SMARTWheel was attached to the right side of the wheelchair to analyse aspects of propulsion technique.

Main Findings

- A motor driven treadmill with a 0.7% gradient best replicated the physiological cost of over-ground propulsion at lower speeds (4 and 6 km•h⁻¹), whereas at the highest speed (8 km•h⁻¹) a 1.0% gradient offered the best representation.
- A 0% treadmill gradient significantly underrepresented the physiological cost of over-ground propulsion, whereas a 1.3% gradient of WERG propulsion overrepresented the physiological cost.
- No laboratory-based modality provided a valid representation of over-ground propulsion biomechanics.

Reference

Mason, B. S., Lenton, J. P., Leicht, C. A. and Goosey-Tolfrey, V. L. (2014). A physiological and biomechanical comparison of over-ground, treadmill and ergometer wheelchair propulsion. *Journal of Sports Sciences*. 32: 78-91.



Illustration of the experimental set-up used during the treadmill testing, with the instrumented SMARTWheel attached to determine propulsion kinetics.

PERFORMANCE HEALTH

Project Prism. Para-athlete retirement: Insights, Support, Management

February 2016

Project PRISM

PARA-ATHLETE RETIREMENT: INSIGHTS, SUPPORT, MANAGEMENT

A collaboration between the Peter Harrison Centre for Disability Sport and the English Institute of Sport's Performance Lifestyle Team

PROJECT OVERVIEW

Background

The EIS Performance Lifestyle Team supports and mentors athletes as they move through the stages of their sport career. To date, there have been no empirical studies of the 'out of sport' transitions of para-athletes and practitioners therefore utilise expertise from health and social care, disability specific charitable organisations and existing able-bodied research.

Research Aims

(1) Document the after sport experiences of retired GB para-athletes. (2) Assess what PL support para-athletes accessed during and immediately following their sport careers and if and how these services assisted them in their transition. (3) Investigate what factors facilitated or impeded their transition from sport with attention to disability specific factors. (4) Identify areas where EIS can have a positive influence on facilitating para-athletes transition from sport and provide guides for best practice grounded in empirical data.

Methods

An online survey was sent to para-athletes who represented GB at a Paralympic Games or international event. Select survey respondents were then contacted for more in-depth interviews. A thematic analysis was conducted using deductive codes from existing literature on athlete transitions and inductive codes developed throughout the course of the work.

An athlete's pathway out of sport is at least as important as his or her pathway into sport and part of an ethical sport system.

SURVEY PARTICIPANTS

-  60 from 24 para-sports responded to the survey.
-  48 were Paralympians and 21 had medalled at a Paralympic Games.
-  21 females and 39 males participated in the project.
-  25 had congenital impairments and 35 had acquired impairments.



PERFORMANCE HEALTH

Wheelchair tennis improves well-being of participants in developing countries

Introduction

Within developing countries, individuals with a disability may experience considerable psychological and social hardship due to negative cultural depictions of disability.

This can result in individuals experiencing low self-esteem, depression, anxiety, and feeling isolated and marginalized from society. Sport has been suggested as a tool which can be used to alleviate the psychosocial burden having a disability can bring, however few studies have investigated how participating in sport impacts people from developing countries. The purpose of this study was to investigate what impact playing wheelchair tennis had on people from developing countries.

Methods

16 wheelchair tennis players from 6 different countries (Morocco, Iran, Romania, Turkey, South Africa and Yemen) were interviewed regarding their experiences playing wheelchair tennis. Data were collected using semi-structured interviews, transcribed verbatim and subject to thematic analysis.



Main findings and applications

- Participating in wheelchair tennis impacted participants in 3 key ways; developed transferable skills, perceived personal growth and the crafting of an athletic identity.
- Skills learnt on the tennis court, such as increased self-confidence, resilience and physical function were transferred to everyday life, improving independence and quality of life.
- Playing wheelchair tennis enabled participants to develop new skills, have different life experiences and forge friendships with people from other countries resulting in perceptions of personal growth.
- Embodying an identity of an athlete enabled participants to challenge negative cultural perceptions both intrinsically and in wider society by minimising stigmatising disability narratives, and showing that they could fulfil the societal roles expected of them.

Reference

Richardson, E. V., Papathomas, A., Smith, B. and Goosey-Tolfrey, V. L. (2015). The psychosocial impact of wheelchair tennis on participants from developing countries. *Disability and Rehabilitation*. 5: 1-8.



The PHC would like to thank the International Tennis Federation for their funding and support throughout this project.

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“The Peter Harrison Centre for Disability Sport is a thriving and productive research unit with strong leadership, engaged staff and students and a committed benefactor. Professor Tolfrey skilfully combines laboratory-based science with practitioner relevant applied research. The new knowledge emerging from the Centre’s vast research engine is always effectively translated and disseminated. The Centre is regarded as world leading in producing disability sport research and it is contributing to the increased success of our Paralympic performances in the UK.”

—



Chelsea Warr
Director of Performance at UK Sport.



—

“I am delighted to acknowledge the support and work of the PHC towards assisting sports and athletes achieve what was a truly historic result at the Rio Paralympic Games. This is a World leading Centre supporting our British athletes being the very best that they can be.”

—

Mitch Hammond
Senior Performance Advisor UK Sport



—

‘Many of the Centre’s projects present opportunities to complete research that has potential to benefit across the full spectrum of activity, from exercise for health all the way through to elite performance and vice versa.’

—

Prof Vicky Tolfrey



COCA-COLA ACTIVE HEALTHY LIVING PROJECT

The main aim of this project was to leverage the inspiration from the London 2012 home Paralympic Games. There is no doubt that our Paralympians changed the views of the general public and hopefully inspired other individuals with a disability to get involved in sport. To capture this interest the PHC developed an educational toolkit to help individuals build on their enthusiasm using disability-specific information.

Fit for Life and Sport guides

The booklets were developed for individuals with a spinal cord injury, cerebral palsy, a visual impairment, amputations and les autres. The booklets cover two levels: Fit for Life, which is aimed at individuals who are just getting started and need to understand the basics, and Fit for Sport, which is aimed at individuals who already exercise regularly but are looking to take sport to a new level. The booklets contain information on exercise and training, nutrition and psychology. These guides hopefully give people the confidence and understanding about how to lead a healthy, more active lifestyle and maybe try something new.

All 5 guides are now available on our website. Please visit www.lboro.ac.uk/phc-toolkit to view and download your own guide and browse some factsheets.



—
“Not everybody wants to be an athlete and everyone has different goals: yours may be to join a sports club, learn how to run using your new prosthesis, or simply to get fit and healthy but whatever they are, don’t let anything get in your way. I am a strong believer in living life without limits.”

—
Richard Whitehead
Amputee ambassador



—
“Having played Wheelchair Rugby for many years I understand the importance of training, nutrition and psychology for the elite athlete. However, overcoming barriers to physical activity and exercise and eating well have become even more important now that I have retired. I may not be an elite athlete anymore but I still want to maintain my health and fitness.”
 —

Andy Barrow
 Spinal Cord Impairment ambassador

Project INSPIRED (Investigating narratives and Stories to promote and Inspire Regular Exercise in the Disabled)

Project INSPIRED is a research initiative that aimed to harness the power of real life stories to motivate people with a spinal cord injury to be physically active. More than 30 participants, male and female of all ages, were asked to share their stories of being physically active. Some were stories of regular exercise, others told of the struggle to stay motivated in the face of numerous obstacles. All participants delivered emotional and heartfelt accounts of their experiences. Based on these stories, Dr Anthony Papatomas and Dr Brett Smith created two fictional stories that tell the tale of a character with a spinal cord injury who becomes more physically active. The stories are used as both an educational resource for health practitioners and as a tool to inspire spinal injured people towards regular exercise.

Physiological markers of physical activity

The aim of this strand of the project was to determine the effect of physical activity on markers of long-term inflammation in wheelchair users and whether the physiological basis for the apparent ‘anti-inflammatory’ effects of exercise would be limited by the small muscle mass used in upper body exercise. Dr Tom Paulson and Dr Lettie Bishop found that one of the key physiological events thought to contribute to the anti-inflammatory effects of exercise; muscle release of IL-6 during exercise, was impaired in those with spinal injuries above T6. Furthermore functional electrical stimulation and handcycling hybrid exercise was able to enhance the anti-inflammatory potential of exercise in individuals with paraplegia. These findings demonstrate the need to develop lesion-specific exercise guidelines to enhance these and other protective effects of exercise on immune and inflammatory responses. This work was continued through an International collaboration with colleagues at the Vrije University, Amsterdam, examining the influence of 16 weeks handcycling and hybrid exercise on inflammatory status in previously inactive individuals with a spinal injury [page 52].

Examples of outreach activities...

Pushing to London 2012 event at Stoke Mandeville stadium

Over 100 people took part in a multitude of activities to learn about disability sport. Attendees learnt wheelchair handling skills during a Top Gear style lap time competition, played Wheelchair Basketball with GB's Emily Scrivener, discussed athlete's healthy eating habits, the benefits of physical activity and took part in a quiz to win signed GB Wheelchair Basketball and Rugby balls. There was also an opportunity for people to learn about the research into disability sport at Loughborough University and the sport science that supports Britain's Paralympians.



Developing physical activity guidelines for people with a spinal cord injury

Researchers from the PHC together with international colleagues from Canada are developing physical activity guidelines to inform people with a spinal cord injury how much exercise to do and how often. Studies have shown that people with a spinal cord injury are among the most physically inactive and deconditioned individuals compared to the general population. Beneficial physical effects of exercise are limited due to muscle paralysis and an impaired nervous system, while people with a spinal cord injury also face many challenges and barriers to physical activity participation.

Together with Prof Kathleen Martin Ginis from the University of British Columbia (Canada), the PHC is building on previous bodies of work to form an evidence-based approach to physical activity guidelines. The outcome of this work, expected in April 2017, will be a set of guidelines regarding the type, frequency, intensity and duration of the exercise which is effective, with the ultimate goal of improving fitness and health.

The process so far... A series of consensus panels have taken place both in the UK and overseas with European, American and Australian academics, as well as clinicians and people with a spinal cord injury. The panels reviewed all the available evidence to reach a consensus on the final guidelines.

Following the successful expert panel meetings, the team presented its work at the International Spinal Cord Society (ISCSO) Annual Scientific Meeting 2016 in Vienna, where the guideline development process was deliberated with international colleagues dedicated to clinical practice, community work and research for people with a spinal cord injury.

There was near-unanimous agreement that guidelines are important to help facilitate physical activity promotion, that consistency across countries is key and that the guidelines should be based on the minimum activity required to achieve health and fitness benefits.

Next steps... A final consensus regarding the scientific guidelines was agreed upon in November 2016, and public and patient engagement activities will help to decide how best to disseminate the guidelines. Over the course of 2017, the PHC and its international colleagues will work with partners including spinal injury charities, disability sport organisations, rehabilitation units and people with a spinal cord injury to tailor the guidelines locally and determine the most suitable format and methods of distributing them to most effectively reach those who will benefit.

—
“Personally I thought the event was amazing, so many different activities, all sorts of advice and inspirational people to meet and talk to. I was really proud to be part of such a motivating and educational event, I hope it leaves a great legacy after the London 2012 Games.”
 —

Emily Scrivener

ParalympicsGB Sports Fests.

The team attended 3 ParalympicsGB Sport Fests across the country to help budding athletes get into sport. The guides were well-received by those attending the events and many were pleased to have the disability-specific information 'all in one place'. People attending the events were able to try a number of Paralympic sports and also meet some London 2012 athletes. The guides were also introduced to all of the winter and summer Paralympic sports in attendance to use with their grassroots clubs and development athletes.



The Very Alternative Guide to Spinal Cord Injury

A fully illustrated spinal injury book like no other: Honest, funny, and informative.

The book is based on PHC Research and aims to provide an accessible and humorous health resource for individuals with a spinal cord injury. Traditional support materials were either heavy reading medical texts or 'safe' information books. The Very Alternative Guide aims to give a 'tell it like it is' account of life with a spinal cord injury, looking at both the positives and negatives of living with this impairment. An advisory board composed of individuals with a spinal injury and healthcare professionals ensured that the content was accurate and suitable. The book has been well-received by people with a spinal cord injury and health professionals working in the field. Helen Smith, Consultant Clinical Psychologist at London Spinal Cord Injury Centre, stated that:

—
"After a spinal cord injury or illness, we know that humour can help, information can help, and support can help. This book brilliantly combines all these elements." Similarly, Dr Sophie Tegg, Psychologist at Duke of Cornwall Spinal Treatment Centre, stated: "There is a depth and range to this book that belies its apparent simplicity. It manages to be informative whilst also being heartfelt and humorous."
 —

The book is currently in the process of being translated into German by a German Spinal Cord Injury Charity.



Photography exhibition at Aspire National Training Centre: 'The Reluctant Heroes'

The photography exhibition displayed visual methods data collected through Project INSPIRED. 15 individuals with a spinal cord injury were invited to take personal photographs representing their experiences of being physically active or inactive. Drawing on contemporary styles of display, the viewer was taken on a visual journey through the trials and triumphs associated with trying to be active following a spinal cord injury. The biographical photography shows us why an active life can be so difficult; but also why it can be so great.

Those in attendance included disability charity personnel, government organisation executives, spinal injury medical professionals and individuals with a spinal cord injury. Guest speaker Andy Barrow, a former ParalympicsGB Wheelchair Rugby Paralympian, delivered an inspiring speech to conclude a hugely successful day. Following the success at Aspire, the exhibition was also displayed at the 4th international Conference of Qualitative Research in Sport and Exercise.



The Paralympic Athlete: An applied perspective. A BASES workshop



PHC members, in association with the English Institute of Sport (EIS) and the National Centre for Sport and Exercise Medicine - East Midlands (NCSEM-EM) delivered a BASES workshop as part of their 2015/16 CPD programme. The workshop aimed to approach Paralympic sport from a multidisciplinary perspective and hence the following programme was delivered:

Paralympic athletes:

The same or different? (Nik Diaper, EIS)

Spinal cord injury:

Limitations and adaptations to training and performance (Vicky Tolfrey, PHC)

Applied Perspectives from Wheelchair Rugby and Para-canoe (Tom Paulson, PHC and Luke Sweet, EIS)

Lab tour, demonstrations and athlete Q&As

(Emma Wiggs (Para-canoe, pictured above), Mike Kerr (Wheelchair Rugby) and Ryan Taylor (Paralympic Triathlon))

Nutritional considerations for the Paralympic Athlete

(Terri Graham, PHC/EIS)

Group needs analysis:

scenarios

—
'It was fantastic how the fundamentals were supported or explained with applied scenarios. Very interactive, case studies, Q & A with Paralympic athletes, credit to everyone who was involved. Great breadth of support staff. It was brilliant and all workshops should be like this.'
 —

Delegate feedback

—
'Great practical workshop with knowledgeable presenters, highly recommend'
 —

Delegate feedback

The Lionheart Challenge Regional Finals at Wembley National Stadium

The London 2012 Paralympic Games were the most successful ever, with our athletes becoming just as famous as their Olympic counterparts. The Paralympic Games marked a change in attitude towards individuals with a disability, removing barriers to sport and showing that an “inclusive approach” is not only possible but can lead to truly inspiring achievements.

The Lionheart Challenge aimed to celebrate the London 2012 Paralympics - and particularly so in schools where they can be used to challenge stereotypes from an early age and motivate students. Hundreds of proactive young people (14 years of age) from secondary schools across London and the South of England came together to compete in a demand-driven and real-time entrepreneurial challenge. The student teams created innovative solutions to help make sport even more inclusive by developing products or programmes which would enable many more individuals with a disability to actively participate in sport. A team of experts from The PHC joined Paralympians Jayant Mistry, Andy Barrow and Mark Fosbrook to help guide the teams with their ideas and presentations.

The students produced some brilliant ideas and plans whilst also developing key skills and business knowledge vital for the creation of confident business people, employees, and employers of the future something which has been ever increasingly reported as lacking within our country.



Professor Tolfrey sat on the judging panel and had the privilege of awarding students with their prizes



Selected invited presentations

Professor Tolfrey and other PHC members have delivered numerous public lectures and invited presentations throughout the 2012-2016 Paralympic cycle. Here are a few examples:

Goosey-Tolfrey, V.L. (2016). Sharing best practice between spinal cord injury rehabilitation specialists and applied sports scientists supporting the Paralympic athlete. 53rd Meeting of the Japanese Association of Rehabilitation Medicine. 9-11th June.

Janssen, T., Flueck, J. and Goosey-Tolfrey, V.L. (2016). Nutrition and Supplements in Wheelchair Sports [Symposium]. International Convention on Science, Education and Medicine in Sport – ICSEMIS. Santos SP, Brazil. 31st Aug-4 September 2016.

Paulson, T. (2016). The prescription and monitoring of exercise intensity in individuals with spinal cord injury: From rehabilitation to sports performance. Reade rehabilitation institute (Amsterdam, 2016).

Fliess-Douer O, Wilber RL, Mason B, Cardinale M (2015). Give the medals to the scientists and engineers. The use of novel technology to enhance wheelchair sports performance. ACSM 62nd Annual Meeting (San Diego, California 2015).

Goosey-Tolfrey VL. (2015). The journey to London and beyond: Supporting the Paralympic athlete. 6th International Sports Medicine and Sports Science Conference, Marina Putrajaya, Malaysia, April.

Goosey-Tolfrey, V.L. (2015). Novel Approaches to Exercise Testing Symposium: Testing functional capacity in Paralympic athletes: Considerations according to classification. Canadian Society for Exercise Physiology's Annual Meeting and Conference (CSEP): Where Science is the New Steel. Hamilton. Canada. 14-17 Oct.

Goosey-Tolfrey, V.L. (2014). Technology and Performance in Paralympic Games. Brazilian IV International Parasports Congress, Florianopolis/SC, 3rd - 7th November.

Workshops

- English Institute of Sport Spinal Cord Injury Education Day (31st Oct 2013) - The Spinal Cord Injured Athlete – Physiological Considerations for Health and Performance with Dr Christof Leicht and Tom Paulson.
- Symposium in Japan (Nov 2014) - Prof Vicky Tolfrey and Dr Christof Leicht organised with Prof Fumihiro Tajima a mini 2-day symposium with an objective to provide opportunities to develop sport science and sport medicine in spinal cord injured athletes and foster relationships between international research centres. The International Symposium of Sport Science in athletes with spinal cord injury in Wakayama, Japan (23-24th Nov).
- Sport, Exercise, and Medicine: International Perspectives on Spinal Cord Injury across the Exercise Continuum (15th Jan 2015).
- BASES. The Paralympic athlete: An applied Perspective. Hosted at Loughborough on the 28th April 2016.



Book chapters

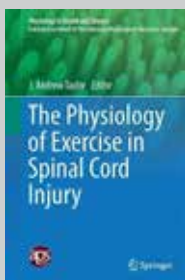
Goosey-Tolfrey, V.L., Paulson, T. and Graham-Paulson, T. (2015). Chapter 16: Practical considerations for fluid replacement for athletes with a spinal cord injury. In Meyer, Szygula, and Wilk. Fluid Balance, Hydration, and Athletic Performance. Taylor and Francis.

The purpose of this chapter was to describe the physiological and anatomical consequences of a spinal cord injury and the main aim was to provide some practical information for coaches and practitioners to fully understand the hydration needs of athletes with a spinal cord injury so that they can apply their knowledge to a condition perhaps beyond their primary area of expertise.



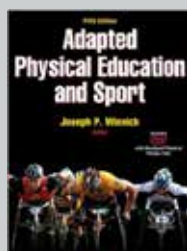
Goosey-Tolfrey, V., Mason, B., and Burkett, B. (2014). Helping athletes excel. In: Handbook of the London 2012 Olympic and Paralympic Games – Volume II, edited by V.Girginov. pp. 169-183. Routledge, London, Taylor and Francis.

The purpose of this chapter was to highlight the role that sport science and technology has had on the performance of Paralympic athletes, with a focus on athletes who rely on a wheelchair or prosthesis for their event.



Leicht, C.A. and Bishop, N.C. (in press) The Effect of Acute and Chronic Exercise on Inflammatory Markers in SCI. In: Taylor J.A. (Ed): The Physiology of Exercise in Spinal Cord Injury. Cambridge MA: Springer.

This chapter describes the consequences of the various levels of a spinal cord injury and their impact on inflammatory markers that are released during exercise. This inflammatory marker release is thought to be beneficial for health and originally thought to be dependent on the muscle mass involved in the exercise. However, recent evidence shows that inflammatory responses comparable to lower body exercise can be seen for activities using a smaller muscle mass (such as upper body exercise), which is a positive finding for individuals with a spinal cord injury.



Goosey-Tolfrey, V. and Mason, B. (2017). Chapter 29: Enhancing wheelchair sport performance. In: Adapted Physical Education and Sport – Volume VI, edited by J.P.Winnick. Human Kinetics. pp. 565-584.

The purpose of this chapter was to document how performance in wheelchair based sports could be achieved by using a systems approach. The chapter addressed means of maximizing performance by considering the athlete, the wheelchair and most importantly the wheelchair-athlete combination.



Fliess-Douer, O., Mason, B., Katz, L., So, R. (2016). Sport and technology. In: Training and Coaching the Paralympic Athlete (ed. Y.C. Vanlandewijck and W.R. Thompson), pp.150-171. Wiley Publishers.

This chapter highlights the important role that assistive technology has on performance monitoring within Paralympic sports and how this has developed over recent years. Topics range from methods of performance analysis and the use of wearable technology through to biomechanical analyses enabled through advancements in technology and their application to a wide range of Paralympic athletes.

PUBLICITY

BBC Breakfast
13th Sept, 2016



LboreRio2016 @LboreRio2016 · 13 Sep 2016
Great to see Prof. Vicky Tatley (@PHC_Lboro) on @BBCBreakfast taking about the specifics of wheelchair racing pic.twitter.com/2256525W6



Faye McClelland, LboreRio2016, Loughborough: Sport and 4 others



East Midlands News 26th July, 2016



Official opening of the NCSEM-EM building and the enclosed PHC laboratory. Professor Vicky Tolfrey with Sir Steve Redgrave and Sir Peter Harrison.



A screenshot of a news article from "THE CONVERSATION". The headline reads "Rio Paralympics: athletes with spinal-cord injuries tend to overheat". The article text discusses thermoregulation and heat loss in athletes with spinal-cord injuries. The author is identified as Kate Whigan. The article includes social media sharing icons and a date of "8th September 2016".



Paratriathlon 220 magazine article June, 2015

The Conversation 8th September, 2016

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from PHC staff and students