ISPO 18th WORLD CONGRESS
virtual edition
1-4 November 2021

Digital Transformation in an Evolving World

ABSTRACT BOOK

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Preface

The World Congress is the flagship meeting of the International Society for Prosthetics and Orthotics (ISPO): a unique interactive event where professionals involved in the care of persons in need of prosthetic, orthotic, mobility, and assistive devices come together to learn about the latest scientific and clinical advances, products, innovative technologies, designs, and materials in prosthetic and orthotic care. The challenges of the pandemic necessitated a shift to our congress planning for 2021, to the first entirely virtual congress for ISPO. Digital technology enables us to bring the ISPO global community together virtually to share our knowledge and experiences.

With the theme *Digital Transformation in an Evolving World*, the ISPO 18th World Congress virtual edition will explore how digital transformation affects all aspects of using and working with assistive technology, from booking a clinic appointment and electronic health records, to computer aided design, microprocessor-controlled protheses or orthoses, or video conferencing and social media. It aims to help the prosthetic and orthotic sector to move forward, making the best use of digital and artificial intelligence technology to provide the best services anywhere in the world. The interdisciplinary programme features 4 Keynote Lectures, 16 Symposia, 12 Instructional Courses, 141 Free Paper and 87 Poster Presentations as well as Exhibitor Workshops. As illustrated in this Abstract Book, the scientific programme highlights the state of the art in prosthetics and orthotics and tries to look beyond current horizons, with the aim of inspiring delegates to work together to create a world where individual rehabilitation needs can be met.

Abstracts submitted for Symposia and Instructional Courses were reviewed by the World Congress Scientific Committee for quality and relevance. Symposia present thematically related research addressing significant problems or controversies in prosthetics, orthotics, mobility and assistive devices, and aim to present differing perspectives on a particular topic through scientific debate. Instructional Courses present information on practical applications of specific topics at a level suited to the practitioner. The focus is on teaching or advancing skills at a Basic or Advanced level. Abstracts submitted for Free Paper and Poster presentations were peer reviewed by external experts invited by the World Congress Scientific Committee for relevance, appropriateness of method and conclusions, and overall quality. The review process for Free Paper and Poster abstracts was double blinded, meaning that author and reviewer information were not shared with either party. The highest ranked submissions were selected for free paper presentation. A Free Paper may describe a technique, case study, case series, clinical trial, systematic review, experiment or qualitative research delivered as a podium presentation during the congress. By comparison with free papers, a poster may present preliminary results or works in progress. Abstract reviewers are acknowledged in this Abstract Book for volunteering their time and expertise. No other remuneration or incentive was provided for their efforts.

The Abstract Book was compiled using Oxford Abstracts. In each abstract, the name of the presenting author is underlined. A limitation of this electronic submission of documents is that figures are often compressed or minimised in size at various times in the process of upload from the authors and compilation into the final Abstract Book. As such, we apologise in advance where figures have not been depicted clearly in this final compilation.

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Congress Programme

Monday, 1 November

Keynote Lecture

1.1
IC2A Inspirational Lecture: Prosthetics for All – Changing Lives through Digital Technologies

Christopher Hutchison

ProsFit Technologies Sofia Bulgaria

Abstract

Christopher became a bilateral lower-limb amputee (BK & AK) in 2009, entering a new and challenging world.

He is inspired by all who work in the prosthetics field, and their dedication to making peoples' lives better. Driven by passion to play his part, in 2013 Christopher co-founded a business in prosthetics, with the vision of "A World where innovation provides limb wearers a choice of affordable, reliable and desirable prosthetic products and services".

In 2014, Christopher became the first person to wear a definitive 3D-printed socket, fully regulated in the EU. This was 7 years ago. Lots of hard work led up to that moment, and even more has happened since.

The prosthetics industry has also in parallel been going through significant challenges, increasingly deploying technology to meet the needs and expectations of prosthetic users.

Christopher knows full well that it is not easy being an amputee. He has been "lucky" to have access to quality and reliable prosthetics, peer support, and other opportunities to improve his mobility. These have formed a foundation, allowing him to grow personally and move ahead in life.

Not everyone is so "lucky", yet. There remains the fact that over 70% of amputees in the world remain without comfortable prosthetics. This is a challenge we all need to address.

The technologies, solutions, approaches and funding are available to tackle this, allowing all of us to increase our impact, both professionally and personally.

Prosthetics for All. It is possible, and together we can make it happen.

Advanced Instructional Course
Prosthetics: Lower Limb

1.2.1
Towards Smart and Intuitive Osseointegrated Transfemoral Prostheses Embodying Dynamic Behaviours

Raffaella Carloni[1], Andrea Zucchelli[2], Erik Prinsen[3], Ruud Leijendekkers[4]

[1]University of Groningen, Groningen, Netherlands. [2]University of Bologna, Bologna, Italy. [3]Roessingh Research and Development, Enschede, Netherlands. [4]Radboud University Medical Center Nijmegen, Nijmegen, Netherlands

Abstract
This Instructional Course aims at presenting MyLeg, a four-year project which has been funded by the European Commission's Horizon2020 Programme in 2018. MyLeg is a collaborative project between the University of Groningen (NL) as coordinator, the University of Bologna (IT), the University of Twente (NL), Roessingh Research and Development (NL), Radboud University Medical Centre Nijmegen (NL), Össur (IS), and Norwest Advanced Orthopaedics (AUS).

The MyLeg project aims at developing both a solid theoretical understanding and the enabling technologies for the realization of a new generation of transfemoral prostheses that can be intuitively operated, sensed, and trusted as the healthy counterpart.

The MyLeg prosthetic system is directly anchored to the amputee's bone by means of an osseointegrated implant to enhance the human-prosthesis interaction, perception, and motion capabilities; it includes intramuscular myoelectric sensors on targeted reinnervated muscles to realize an intuitive EMG control and to provide a high-level of cognition abilities; it relies on composite materials to achieve compliance and light-weight; it implements variable stiffness actuators that guarantee high adaptability with respect to different tasks, dependability, and decisional autonomy.

This Instructional Course aims at showing the scientific community the latest developments of the project. After three years of research activity, the MyLeg prosthetic system has undergone the first successful experimental tests with amputee patients and the MyLeg Consortium is ready to share some results. Specifically, the main topic that will be discussed are:

- The mechatronic advances on the development of a novel powered transfemoral prosthesis
- The lesson learned on osseointegration
- The amputees experience

Statement of the learning objectives
Attendees should expect to enrich their knowledge on the mechatronic development of an intuitive transfemoral prosthesis, and to learn about osseointegration from both the surgical/medical perspective and the patients' experience.

Free Paper Session
Orthotics: Lower Limb – Ankle Foot Orthoses

1.2.2.a

Comparison of Sagittal Plane Stiffness of Non-Articulated Paediatric Ankle-Foot Orthoses Designed to be Rigid

Stefania Fatone[1], Elaine Owen[2,3], Fan Gao[4], Garth Shippen[5], Michael Orendurff[6], Kristie Bjornson[7,8]

[1]Northwestern University, Chicago, USA. [2]London Orthotic Consultancy Ltd., Surrey, United Kingdom. [3]Child Development Centre, Bangor, United Kingdom. [4]University of Kentucky, Lexington, USA. [5]Hanger Clinic, Bellevue, USA. [6]Oregon Biomechanics Institute, Ashland, USA. [7]Seattle Children's Hospital Research Institute, Seattle, USA. [8]University of Washington, Seattle, USA

BACKGROUND

When studying the effect of ankle-foot orthoses (AFOs) on gait, it is important to know their sagittal plane stiffness because it helps explain the effect of AFOs on gait kinematics and kinetics [1]. However, there are no established thresholds for stiffness of non-articulated AFOs designed to be rigid [2]. Hence, if implementing published algorithms for ankle-foot orthosis-footwear combinations (AFO-FCs), it is important to confirm that the AFOs are equally stiff as those of the developer of the AFO-FC algorithms [3].

AIM

To compare the sagittal plane stiffness of AFOs designed to be rigid, made in the USA and following algorithms for AFO-FC designs, to those made and used in the UK by the developer of the AFO-FC algorithms.

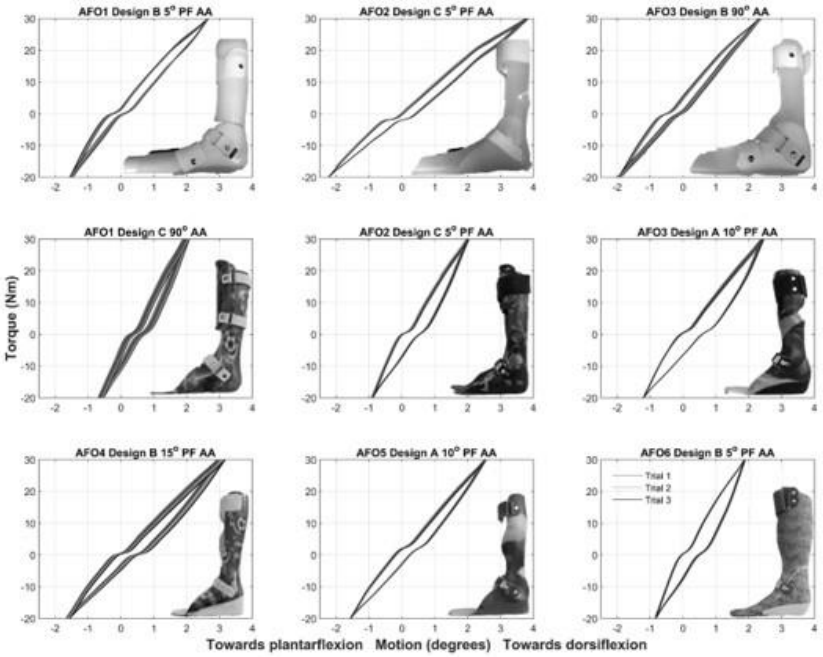
METHOD

Stiffness of 9 paediatric polypropylene AFOs was tested (UK: 6; USA: 3). A computer controlled motorized device was used [4] in which all AFOs were clamped with the calf shell in a fixed vertical component and the foot section in a rotating plate. Each AFO was tested for 3 trials, loading the foot plate 30 Nm towards dorsiflexion and 20 Nm towards plantarflexion. Torque-angle graphs were plotted and deflection and stiffness compared descriptively across AFOs.

RESULTS

AFO designs tested and torque-angle graphs are shown in Figure 1. Average deflection of AFOs was UK: 3.42±0.83° and USA: 4.81±1.05°. Average stiffness of AFOs was UK: 14.34±3.34 Nm/° and USA: 10.30±1.92 Nm/°.

Figure 1 Torque-angle graphs for 3 trials of each ankle-foot orthosis (AFO).



DISCUSSION AND CONCLUSION

All tested AFOs deflected only a few degrees in either direction (range: 2.59º to 6.02º), providing the first information reported for the stiffness of rigid paediatric non-articulated AFOs. Overall, the UK AFOs were stiffer and deflected less than the USA AFOs. AFO design features such as optimum material for height and weight, ankle rib reinforcements, and trim lines anterior to the malleoli should be carefully considered as they likely influence sagittal plane stiffness and deflection under load.

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ACKNOWLEDGEMENTS: This work was supported by the National Institutes of Health Award #R21HD094823.

1.2.2.b

Effect of Ankle-Foot Orthoses on Functional Outcome Measurements in Individuals with Stroke: A Systematic Review and Meta-Analysis

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BACKGROUND
Stroke is a common neurological impairment resulting in reduced functional mobility due to decreased independence in ADLs. The improvement of gait stability and physical function is a primary goal of rehabilitation following a stroke. Clinical measurements with acceptable levels of reliability and validity can be used by health care providers to evaluate the recovery of the patient's functional ability in response to rehabilitation interventions. Ankle-foot orthoses (AFOs) are frequently prescribed to improve ambulatory function during stroke rehabilitation.

AIM
The purpose of this systematic review and meta-analysis was to determine the effect of AFOs and comparison among them on functional outcome measurements in individuals with stroke.

METHOD
This review was performed based on the PRISMA guideline. PubMed, ISI web of knowledge, Embase, Scopus, ProQuest, and Cochrane were searched from inception until June 2020. The methodological quality assessment of 30 included studies was conducted based on the Downs and Black checklist. Functional indices were pooled in accordance with their standardized mean difference (SMD) and 95% confidence intervals (CI) in a random-effect model. A narrative analysis was performed where data pooling was not feasible.

RESULTS
The overall pooled results indicated a significant improvement in favour of an AFO versus without it in Berg balance scale (BBS) (SMD:0.54, CI: 0.19 to 0.88), timed-up and go test (SMD: -0.45, CI:-0.67 to -0.24), functional ambulatory categories (FAC) (SMD:1.72, CI:1.25 to 2.19), 6-minute walking test (SMD:0.91, CI:0.53 to 1.28), timed-up stair (SMD:-0.35, CI:-0.64 to 0.05), and Motricity Index (SMD: 0.65, CI: 0.38 to 0.92). Heterogeneity was not significant in the outcomes (I^2 <50%, p>0.05) except for BBS and FAC.

Although the narrative analysis showed some improvement in many functional outcome measurements using an AFO such as Timed Down Stairs, Functional Reach Test, *Modified Ashworth Scale*, Functional Independence Measure, the modified Emory Functional Ambulation Profile (mEFAP), Barthel Index, and Rivermead Mobility Index, there were insufficient studies for reaching a valid conclusion. In addition, there was no sufficient evidence in the effectiveness of specific AFO designs over others.

DISCUSSION AND CONCLUSION
An AFO can improve ambulatory function in survivors of stroke and that an AFO is more effective on functional outcomes with long-term adaptation. Rehabilitation care during subacute phase wearing an AFO may have beneficial effects on clinical outcomes measured in individuals with stroke. Future studies should explore long-term effects of rehabilitation care wearing AFOs and comparison of differences in AFO designs.

ACKNOWLEDGEMENTS: The authors would like to thank Dr. Corien Nikamp for providing us additional data for the meta-analysis.

1.2.2.c

Selection of Ankle-Foot Orthosis Shank to Vertical Angle in Adults with Neurological Conditions: A Literature Review

Joshua Young

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BACKGROUND

Selection and adjustment of the shank to vertical angle (SVA) static alignment of ankle-foot orthoses (AFOs) is essential [1]. The normal value for SVA alignment at temporal midstance of barefoot walking is approximately 10-12° inclined [2]. A review of optimised SVA static alignment values for paediatric AFO users has been reported [2] but no review exists for adult AFO users.

AIM

To identify reported optimised SVA static alignment values for adult rigid AFO users with neurological conditions.

METHOD

A non-systematic review was conducted in February 2021 using PubMed and Google Scholar for years 1990 to 2021. Search terms included ‘ankle-foot orthosis’, ‘tuning’ and ‘shank vertical angle’. Reference lists of selected studies were reviewed in addition to articles known to the author. Papers were reviewed to ascertain diagnosis, reported static SVA alignments, SVA measurement method, and method used to select the optimum SVA for each patient.

RESULTS

Six studies were identified: one reported target values rather than actual optimised values; one reported range of optimised values only and four studies reported optimised static SVA values (table 1) [3–6]. These 4 studies included patients with diagnoses of: stroke (CVA) (n=6); spinal cord injury (SCI) (n=2); traumatic brain injury (TBI) (n=1); peripheral neuropathy (PN) (n=1). Mean optimised static SVA alignment was 11.7° incline (range 10-14°) for all subjects and 12.3° (range 10-14°) for stroke. Methods used for determining optimal SVA and measuring SVA static alignments were not always clearly described.

Table 1

Study	Population	Optimised static SVA (degrees incline)
Jagadamma et al. 2010 [5]	CVA (n=1)	14°
Choi et al. 2016 [6]	CVA (n=1)	12°
Young et al. 2019 [3]	CVA (n=4) SCI (n=2) TBI (n=1)	10°,12°,12°,14° 11°,11° 11°
Young 2020 [4]	PN (n=1)	0° progressing to 10°

DISCUSSION AND CONCLUSION

This review reports the limited data available for optimised static SVA alignment values selected for adults with neurological conditions. The optimised SVA values are similar to those reported for children, which were 7-15° (mean 11.4°) [2]. Optimal SVA values may vary, depending on the underlying pathology and gait pattern. Further research on selecting optimal SVA static alignments in adults with neurological conditions is needed. Future work should specify the methods used to select and measure SVA.

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1.2.2.d

A Review of Accuracy of Web Based Information about Ankle-Foot Orthoses in the Management of Cerebral Palsy

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BACKGROUND

Cerebral palsy is one of the most common childhood motor disabilities, and ankle-foot orthoses (AFOs) are commonly used as part of the treatment plan. People who are prescribed AFOs, and their families and carers will often search online to find information about AFOs. However, little is known about the accuracy of online information about use of AFOs for cerebral palsy.

AIM

The aim of this study was to assess the accuracy and quality of internet information aimed at patients and their families or carers, about AFO use in the management of cerebral palsy, by comparing identified websites to evidence-based practice.

METHOD

An accuracy checklist was created, based on ISPO's Consensus Conference on Cerebral Palsy [1]. This was supported with an up-to-date literature search of relevant literature between 2009-2020. A quality checklist was created which was informed by the Health On the Net (HON) guidelines [2]. If websites meet these guidelines they can apply for HON certification, to demonstrate they meet quality guidelines. The next stage of the process involved a web search of terms relevant to AFOs and cerebral palsy using three search engines, to identify relevant web pages to review. These web pages were then assessed for accuracy and quality using the created checklists.

RESULTS

Twenty-nine websites were identified as meeting criteria for further analysis. Three (10.34%) websites were categorised as academic; eighteen (62.07%) commercial; one (3.45%) government and seven (24.14%) non-governmental organisations. Important aspects of AFO interventions which were inadequately addressed by the web sites included: the role and responsibilities of the orthotist; AFO design; aims and benefits of AFO use; and risks of AFO use. The quality of the websites varied across different website type and also within these types. Only one website displayed Health on the Net certification, demonstrating an acceptable quality of information provided.

DISCUSSION AND CONCLUSION

Websites have an important role to play in patient education. This project has identified areas of concern regarding accuracy and quality of frequently found websites when searching AFO use in cerebral palsy. Clinicians may need to address these information gaps during consultations.

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1.2.2.e

Parental and Clinician Lived Experiences of the Ankle Foot Orthoses Footwear Combination (AFO-FC) Management Approach in Cerebral Palsy (CP)

Kristie Bjornson[1], Molly Fuentes[1], Ana Christiansen[2], Stefania Fatone[3]

[1]Seattle Children's Research Institute/University of Washington, Seattle, USA. [2]Therapeutic Research in Neuromuscular Disorders Solutions (TRiNDS), Seattle, USA. [3]Rehabilitation Medicine/Northwestern University, Chicago, USA

BACKGROUND

A novel algorithm for orthotic prescription proposes a patient-specific method for adjusting AFO alignment and integrating footwear modifications (Ankle Foot Orthoses-Footwear Combinations, AFO-FC).[1,2] The goal of AFO-FCs is to improve stability by facilitating more normal segment kinematics in single limb stance and decreasing excessive hip/knee flexion. This approach includes modifications internally to the rigid AFO and/or externally to the shoes, and multiple fitting visits with the orthotist, thus potentially influencing the acceptability/tolerance of by child/family.

AIM

The purpose of this project was to describe the lived experience of families and clinicians implementing the AFO-FC intervention in ambulatory children with cerebral palsy (CP).

METHOD

A qualitative informant interview study was conducted with informed consent. Subjects included mothers of children with spastic diplegic CP (Gross Motor Function Classification System levels II (n=7), III (n=3)), wearing AFO-FC and clinicians (7 orthotists, 3 physical therapists) who implemented AFO-FC. Children received joint orthotist/therapist visits at assessment, fitting and follow-up. Guided interviews were conducted by phone (n=20). Participants were asked what they liked/did not like about the AFO-FC, how it compared to other approaches, and suggestions to improve management. Responses were manually scribed during interviews. Three investigators individually reviewed and coded the transcripts for common themes. Final themes were determined when all 3 investigators reached consensus.

RESULTS

Table 1 summarizes parent and clinician themes illustrated with an exemplar quote.

Themes	Exemplar Quotes
Standing Quality	“Child is more upright with better alignment of bones/joints.”
Walking Skills	“Can walk straighter, taller & longer periods without complaint of pain or fatigue, more heel strike.”
Mobility in Daily Life	“Runs with friends everywhere.”
Tolerance	“Wears them all day long, less skin breakdown.”
Shoe Issues	“Big and bulky, transitions between activities take on/off. Wearing clown shoes.”
Extra Visits	“Adjustments when walking changes.”
Device Mechanical Effect	“Correcting versus accommodating for biomechanical misalignment."
Outcomes	“I (orthotist) never knew if devices/shoes worked or not. I would only see the patient when there was a problem/skin issues [with] combined visits (therapist & orthotist), now see effects; Optimized devices & shoes affects gait training.”

DISCUSSION AND CONCLUSION

Positive and negative themes about implementation of the AFO-FC approach were documented by parents and clinicians. Results may be unique given the singular site, from which subjects were recruited and their experience of joint therapist/orthotist visits, which are not common practice. The results highlight tension between positive functional results and the bother of the intervention. While further study is needed, results suggest framing expectations at treatment outset is important along with consideration of combined provider visits.

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ACKNOWLEDGEMENTS: Funding support: NIH K23 HD060764.

Free Paper Session
Healthcare Policy and Services

1.2.3.a

Identifying Challenges and Facilitators to the Implementation of Digital Technology in the Field of Orthotics & Prosthetics: A Qualitative Study

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BACKGROUND
Although many orthotics and prosthetics (O&P) practitioners believe the use of digital technology such as 3D scanning and additive manufacturing will continue to grow and become more prevalent within the industry [1], literature on its use in O&P is fragmented with reviews suggesting that there is much work to be done before widespread clinical implementation is possible [2]. Therefore, there is a need to understand the specific challenges to implementing digital technology in O&P practice.

AIM
This study aimed to identify the challenges and facilitators affecting the implementation of digital technology in O&P by interviewing O&P professionals and to provide recommendations for facilitating the wide adoption of digital technology in the industry.

METHOD
Ten (n = 10) interviews were conducted via video conference and followed a semi-structured interview guide created for the study. Participants were recruited from O&P professional organizations to ensure a diverse representation. All interviews were audio-recorded and transcribed. Inductive thematic analysis was performed on the interviews and emerging themes related to the aims of the study are described in the results to analyse and identify key themes in the data. A qualitative data analysis software, NVivo Pro 12 (QSR International, Burlington, Massachusetts), was utilized to help organize and analyse the collected data.

RESULTS
Three key themes emerged from the data. Results suggested that the widespread adoption of digital technology in O&P practice would require a mindset shift in the field that includes practitioners, O&P organizations, and education and training centres. Additionally, O&P organizations and technology providers need to work collaboratively to establish implementation plans that cater to the needs of O&P organizations. Practitioners highlighted the importance of continual training and technical support to ensure sustainable success and continued penetration of technology within their practice. But ultimately, the paucity of scientific research and clinical evidence related to the applications of digital technology has hindered its spread of adoption. Therefore, more research, development, and validation of digital technology for O&P use is essential to building trust and confidence within the O&P community.

DISCUSSION AND CONCLUSION
It is important to remember that the goal is not to replace traditional practice with a digital one. Rather, digital technology should be perceived as another tool for practitioners to utilize. We need to find a solution to marry the clinical expertise and hands-on experience of practitioners and the power and efficiency of digital technology to improve the fabrication process and quality of the product, and ultimately, continue to improve the quality of patient care.

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ACKNOWLEDGEMENTS: We wish to thank Neil Ready, Elaine Ouellette, and all the participants in this study.

1.2.3.b
The Emergence of Telehealth in Orthotic Services Across the United Kingdom

Nicky Eddison[1,2], Aoife Healy[2], Sian Calvert[2], Nachiappan Chockalingam[2]

[1]The Royal Wolverhampton NHS Trust, Wolverhampton, United Kingdom. [2]Staffordshire University, Stoke on Trent, United Kingdom

BACKGROUND
COVID-19 has had a significant impact on health provision across the globe, creating urgency for health services to adapt and adopt new ways of delivering healthcare. Telehealth has been used to try and ensure clinical services continue to provide patient care. It has become an efficient solution for safe patient care allowing the patient healthcare access without the need for an in-person visit [1].

AIM
Service evaluation to determine the impact of COVID-19 and the emergence of telehealth in orthotic services in the National Health Service, across the UK.

METHOD
A survey exploring telehealth use in orthotic services was distributed online to orthotists approximately 6 months after the first peak of COVID-19 in the UK. It gathered information on the closure of orthotic services, the prevalence of telehealth, allocated appointment length and waiting times, clinician access to required technology and clinicians' opinions on the efficacy of telehealth appointments.

RESULTS
The survey received 77 responses with a substantial number of respondents reporting that their orthotic service was closed, or open only to in-patients and urgent patients, at some point during the COVID-19 pandemic (see Figure 1). Over 90% of respondents reported that they had utilised telehealth appointments, and 73% expected telehealth appointments to remain part of the service, post COVID-19, in some capacity. Thematic analysis produced two main themes: 1) the impact of COVID-19 and 2) challenges still to overcome. Findings suggest that the pandemic has resulted in a backlog of patients waiting for an orthotic appointment, with services currently understaffed and lacking resources.

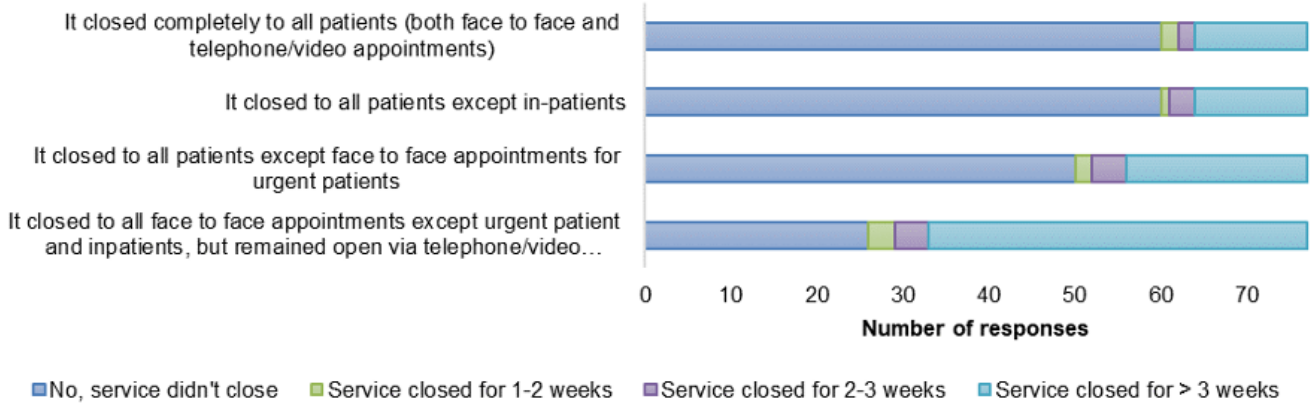

Figure 1: Responses to the question "Did your orthotics service close during the COVID-19 pandemic?"

DISCUSSION AND CONCLUSION
COVID-19 has had a significant impact on orthotic service provision in the UK; with face-face appointments largely reserved for urgent patients and in-patients, and services going through stages of re-opening to routine patients. Most orthotic services have adopted telehealth to ensure access to treatment. Orthotists must have access to appropriate technology and training on how to use telehealth platforms, provided with appropriate guidance on which patients are appropriate for telehealth, and given appropriate appointment times to enable safe and effective care.

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1.2.3.c
Benchmarking Statement for Prosthetics and Orthotics Services in Lebanon

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BACKGROUND
In Lebanon there is an absence of a unified and standardised approach to the prosthetic & orthotic (P&O) sector. Lebanon identified the need to create a more unified sector through undertaking a benchmarking process to compare the situation with the World Health Organization (WHO) Standards for P&O [1].
The final benchmark statement makes recommendations for improving the sector in line with the 4Ps outlined in the standards of policy, products, personnel and provision of services.

AIM
The Benchmark Statement and its recommendations aim to pave the way for the P&O sector to progress and to develop a long-term 2030 vision for Lebanon as well as highlight a systematic approach for P&O services globally.

METHOD
The benchmarking process commenced with a systematic desk review addressing key research questions:

- services to improve function and participation for 3 population groups;
- health conditions accessing P&O services;
- what policies exist;
- what personnel provide services; and
- what services exist in Lebanon.

The desk review [2] combined with the WHO standards were utilised as key documentation for a national summit with 60 participants, subsequent workshops with service providers and service users (via a survey) to help inform the final benchmarking statement.
This benchmark statement compares 60 WHO standards across the four areas of service provision with Lebanon's situation and makes recommendations for development for each standard.

RESULTS
The results demonstrate that this baseline assessment for P&O services in Lebanon, highlights the need for positive development within the sector and identifies key areas for improvement and action within the four key areas of the WHO standards: policy, products, personnel and provision of services.
This publication is a decisive step towards strengthening universal health coverage and working towards the 2030 Sustainable Development Goals, making sure that “no one is left behind” [3] and will be instrumental in developing the sector globally by demonstrating a systematic approach to benchmarking for the P&O sector.

DISCUSSION AND CONCLUSION
Next steps for development for the sector will include working with key stakeholders to develop a long-term vision and implementation plan for Lebanon’s P&O sector by 2030 with key tangible outcomes that can be achieved in Lebanon’s current situation. This approach will be multifactorial ensuring P&O personnel and service users as well as stakeholders are included in the development of the sector.

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ACKNOWLEDGEMENTS: ICRC, Ministry of Public Health Republic of Lebanon, ISPO Lebanon, Rehabskills Limited and Monhem Arab and Ahmad Mawla. Ethics approved by Balamand University IRB number REC/O/014-21/4320.

1.2.3.d

Prosthetists and Orthotists Work Experience in Cutting Edge Technology – Characterized the Workplace and Individual Factors

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BACKGROUND
Intensive development in the field of prosthetics and orthotics change from a craft-based industry into a modern clinical specialty. The demand for Prosthetist and Orthotist is increasing as the global burden of disease increase internationally. To health and safety meet for the orthotist/prosthetists has not been well explored, despite anecdotal evidence from clinicians suggesting that they are exposed to within the workplace environment exposed to a range of physical and psychosocial hazards linked to risks of injury and disease.

AIM
The purpose of this study to identify the causes of occupational health and safety in the workplace such as physical and psychological and environmental work practice in Prosthetists/Orthotists organizational/clinical setting.

METHOD
The author identified participant as focus groups through personal or telephonic discussions those are practice as a graduate P&O minimum of 1 year in Delhi India. A total of 15 P&O agreed to participate and provide demographics data and consent. Data were thematically analysed to identify physical, psychological, and environmental work experience. Questions were prepared based on the conceptual framework and relevant literature following workplace factors was included:

- Job Demand (quantity, intensity, time frames, physical and mental)
- Coping resources (self-esteem, situation, strategy, and social support)
- Individual factors (occupational stress, autonomy, support, job security)

The Focus group explored the factors affecting Prosthetist/Orthotist work experience.

RESULTS
Three major following factors identified as problematic:

- Job Demand and Designs
- The imposition of work factors
- Individual impacts

The Demand of work Practice highlighted factors classified as a hazardous job, or task demands and sub-factors of workloads, time pressure, work environment/ location, work environment, and the physical requirements of the P&O. The factors impact on P&O professional included factors cognitively demanding aspects of the P&O job role, management issues impacting the individual and physical environment impacts, Job design incorporated the sub-factors variety of work, job security, and autonomy.

The result indicated hidden factor perception highlighted to indicate the poor understanding of the nature of work undertaken by Prosthetist/Orthotist and an, in particular, the assessment, diagnosis, fabrication, follow- up and the management of the whole of the body.

DISCUSSION AND CONCLUSION
This study is to explicate a conceptual framework of occupational health and safety in the P&O profession identifies a number of important physical, psychological issues, including characteristics identified as risk factors for work-related musculoskeletal disorders. Findings from the study indicate that some organizations poor understanding of the P&O job role, which results in inappropriate expectations of P&O professionals. The strategic workstream committee is to enhance cooperation and facilitation in relation to a comprehensive risk management approach.

Symposium
Prosthetics: Lower Limb

1.3.1
Scientific Principles of Prosthetic Foot Design

Tim Bryant[1,2], Mike Rainbow[1,2], Urs Schneider[3], Susanne Wrede[4], Stacey R. Zhao[1], Heinz Trebbin[5], Lauren Welte[6]

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Abstract
The objective of this symposium is to present biomechanical principles underlying prosthetic foot design and how these are reflected in performance evaluation and user experience. There will be a focus on recent literature that has examined the role of passive structures in managing energy within the natural and prosthetic foot during gait and running. In particular, these studies have shown how both the magnitude and timing of passive energy storage and release influence mechanical behaviour. Four presentations will explore the biomechanics of the natural foot, the design of bio-inspired and ESAR prosthetic devices, performance evaluation, and user experience. A novel format will feature speakers joined by remote co-presenters.

Moderators: Tim Bryant, Ph.D. (P.Eng.) and Heinz Trebbin, M.Sc. (CPO)

Presentation 1: Biomechanics of the Foot. Anatomy of the foot and how elements of the natural system move and manage force, displacement and energy. Particular emphasis on the Achilles tendon, windlass, and arch-spring mechanisms. Mike Rainbow, PhD with co-presenter Lauren Welte, PhD.

Presentation 2: Anatomical and Energy Storage Prosthetic Foot designs. How bio-inspired devices function and with a review of the research underlying their design and use. Dr. med Urs Schneider.

Presentation 3: Testing and Performance Evaluation. How devices that have elements of both bio-inspiration and energy storage are tested, including ISO, L-code and P-code methods. Stacey Zhao, PhD with Tim Bryant, PhD.

Presentation 4: Clinical experience: Prosthesis users, who are also rehabilitation clinicians, describe how the application of these scientific principles affect the user response. Susanne Wrede, Physiotherapist, with clinician co-presenters.

Statement of the learning objectives
Participants will gain knowledge of recent literature in passive energy management in the natural and prosthetic foot and how these concepts might be integrated into the design, evaluation, selection and fitting of prosthetic foot components.

Advanced Instructional Course
Sports and Physical Activity

1.3.2
Orthotic and Therapeutic Approach in Sports – From Prevention to Rehabilitation

Merkur Alimusaj[1], Martin Engelhardt[2], Sabrina Erdrich[3], Nils Petersen[4]

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Abstract
Sports activity in leisure time or at a professional level is recognized as an important element of an adequate quality of life in large parts of the population today. Likewise, we have reached enormous levels in the field of competitive sports, which also always require mental and physical fitness at the highest level. Therefore, special attention should be paid to protecting the musculoskeletal system before or regenerating it after an injury. The session will focus on the preventive and therapeutic aspects of overuse symptoms in sports. You will get an overview of the medical and training science background. Surgical therapies as well as conservative and physical therapy for overuse symptoms will be shown. In addition, the possibilities of orthopaedic technology are examined under the aspect of therapeutic interventions. Opportunities and limits of orthotics should be examined based on the principle of biomechanical and technical backgrounds. Finally, the audience will get an insight into current digital processes for the fast and efficient supply of athletes with individual orthoses. Especially in high-performance and professional sports, adapted treatments and solutions are essential - this could decide between victory and defeat in competitive sport or between activity and passivity in popular sport. Therefore, this session will shed light on different aspects from the point of view of different professions.

Statement of the learning objectives
The audience will be able to understand new findings and modern diagnostics enabling us to implement differentiated treatment concepts today, with operative and conservative methods used in a process-adapted and goal-oriented manner.

Free Paper Session
Rehabilitation Medicine and Surgery: Lower Limb

1.3.3.a
Lower Limb Amputations in Sweden: Incidence, Time Trends, and Regional Variations

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BACKGROUND
Epidemiological studies on temporal changes in incidence of lower limb amputations (LLA) and their regional variation in Sweden are scarce. Previous reports have either excluded partial foot amputations or not distinguished between amputations above and below the knee [1].

AIM
The aim of the study was to examine the national time trend and regional differences in incidence of LLA in Sweden over the recent 10 years.

METHOD
Data on all incident (lifetime first) LLA on people 18 years and older were identified using relevant procedure codes recorded in the national inpatient register between 2008 and 2017. Amputations were categorized into three levels: 1) high proximal (through or above the knee), 2) low proximal (below the knee), and 3) partial foot amputations (excluding toe amputations). Poisson regression models were fitted to estimate amputation incidence rates and their annual changes with adjustment for age (10-year groups) and sex. Regional variation was examined at county-level, which divides Sweden into 21 regions. Rates are shown by per 100,000 inhabitants.

RESULTS
The LLA incidence (all levels combined) significantly decreased during the period due to a decrease of high proximal and low proximal amputations (Table 1). No significant change of partial foot amputations incidence was observed. The ratio of the highest to lowest amputation incidence among regions was 1.9 for all LLA levels combined, 2.6 for high proximal amputations, 3.2 for low proximal amputations, and 27.0 for partial foot amputations. The incidence of all LLA decreased in 9 regions and was stable in 12 regions.

Table 1. Amputation incidence (per 100,000 inhabitants), regional variation and time trends.

Amputation levels	N (%)	National incidence	Regional variation, min–max	Incidence change/year, (95% confidence interval)
All amputations	16,941 (100)	22.1	17.6 – 34.3	0.984 (0.973 – 0.994)
High proximal	7,051 (41.6)	9.2	6.4 – 16.6	0.985 (0.974 – 0.995)
Low proximal	8,207 (48.4)	10.7	5.2 – 16.4	0.973 (0.962 – 0.984)
Partial foot	1,683 (9.9)	2.2	0.2 – 5.4	0.994 (0.974 – 1.014)

DISCUSSION AND CONCLUSION
The national LLA incidence has declined, which is similar to previous reports [1]. However, not all parts of Sweden are part of this favourable trend, and regional variations may be larger than previously suggested. A potential study limitation was that toe amputations were excluded, but this was a deliberate choice to focus on substantial amputations. In conclusion, amputation incidence has decreased but regional variations in incidence, time trends, and amputation levels call for more research.

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1.3.3.b
Epidemiology of Limb Amputation in Scotland

Sarah Day, Arjan Buis

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BACKGROUND
Incidence of amputation is well documented with variations in gender, ethnicity, and geography being noted. UK data, particularly in the non-diabetic population is however lacking. To understand the needs of the population and determine how we should be directing prosthetic services we must first understand the demographics of those who are born with a limb difference or undergo limb amputation. This study uses amputation data rather than data from prosthetic clinics to calculate incidence and compare trends across Scotland.

AIM
Capture detailed information about the population of people living with limb difference in Scotland, and the medical services which they receive.

METHOD
Using data linkage of routinely collected health records we reviewed the amputation and treatment records, and demographic profiles of all persons who had undergone an amputation or been born with a congenital limb deformity in Scotland from January 2012 to December 2020.

RESULTS
In excess of 10,000 cases were reviewed, which included persons undergoing upper limb amputation, lower limb amputation and those being born with a limb difference.

DISCUSSION AND CONCLUSION
The incidence of amputation in Scotland has remained constant with the exception of 2020 when cases dropped. Variations were identified within the following areas; demographic profile, geographic location, social-economic background, and mortality after amputation.

ACKNOWLEDGEMENTS: This work, funded by The Centre of Excellence in Rehabilitation Research (CERR), uses data provided by patients and collected by the NHS as part of their care and support.

1.3.3.c

Surgical and Rehabilitation Outcomes in the Scottish Population of Patients Undergoing Knee Disarticulation Compared to Transfemoral Amputation

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BACKGROUND

Knee disarticulation amputation (KDA) offers multiple functional advantages over transfemoral amputation (TFA) but often gets overlooked due to a reputation of poor primary wound healing. Previous studies investigating outcomes of KDA have been limited by small and homogenous samples[1,2,3,4]. Previous studies have not made comparisons between TFA and KDA or included rehabilitation outcomes[5,6,7]. A large dataset including KDA and TFA surgical and rehabilitation data is needed for comparison.

AIM

To compare surgical and rehabilitation outcomes for KDA and TFA using a large retrospective dataset.

METHOD

A retrospective analysis of data from the Scottish Physiotherapy Amputee Research Group database for all KDA and TFA from 1 January 2007 to 31 December 2017. We included all KDA and TFA of all aetiology, including reamputation procedures and bilaterals. We excluded all other levels. Each amputation was considered as the unit of analysis for surgical outcomes. Unilateral final level amputees were used as the unit of analysis for rehabilitation outcomes. Data analysis was performed using SPSS Version 25. Statistical significance was set at $p<0.05$ and confidence intervals of ≥95% were assumed. T-tests were used to compare cohorts with continuous outcomes and Chi-squared or Fischer's-exact for cohorts with categorical variables.

RESULTS

4,197 amputations were included for analysis, including 3,471 initial TFA and 146 initial KDA. Of those, 2,967 were final unilateral TF amputees and 91 were final unilateral KD amputees. The mean age was 69 (SD 13) years. The initial KDA group were 3 years younger than initial TFA (p=0.048). 10% of KDA were reamputated to a higher level compared to 0.2% of TFA (p=0.0001) Mortality was 18% in both groups. 25% of KDA and 24% of TFA limb fitted. Median LCI-5 change was -13 for both groups. Time-to-event data is presented in table 1.

Table 1

	KDA median days	TFA median days
From operation to inpatient discharge	35 (17 – 73)	42 (20 – 77)
From operation to casting	22 (14 – 75)	21 (12 – 48)
From inpatient discharge to discharge from prosthetic rehabilitation	99 (5-207)	133 (45 – 230)

DISCUSSION AND CONCLUSION

KDA is associated with some promising outcomes. It is less traumatic and resulted in shorter length of inpatient stay and a more rapid rehabilitation with a prosthesis. The penalty for this was a higher reintervention rate, though this is lower than in older series[2,6]. Study limitations include: despite the large dataset only 23 KDA limb fitted patients were available for analysis of rehabilitation outcomes. The patients were not randomised. Prospective randomised studies are urgently needed to inform clinical practice.

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ACKNOWLEDGEMENTS: This study was funded by the British Society of Chartered Physiotherapists in Amputee Rehabilitation.

1.3.3.d
Views of Knee Disarticulation from the UK Vascular Surgery and Amputation Workforce

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BACKGROUND
Knee disarticulation amputation (KDA) offers multiple functional benefits such as the ability to end weight-bear, prosthetic self-suspension and better sitting balance. Its use is recommended in key guidelines[1,2] yet less than 4% of annual major lower limb amputations in the UK are KDA[3]. We do not know why such a small proportion of potentially eligible patients undergo KDA and if the above-mentioned functional advantages are borne out in clinical practice.

AIM
To explore experiences and perceptions of KDA from specialist clinicians in vascular surgery and amputee rehabilitation.

METHOD
An online survey was sent to members of the Vascular Society of Great Britain and Ireland (VSGBI), British Association of Chartered Physiotherapists in Amputee Rehabilitation (BACPAR), Scottish Physiotherapy Amputee Research Group (SPARG), and the British Association of Prosthetists and Orthotists (BAPO). The survey used open and closed questions informed by current literature; and adapted to the focus of each clinical group following consultation and piloting. Content analysis identified categories and their frequency of occurrence.

Face-to-face and telephone follow-up interviews were completed with six physiotherapists, five prosthetists and 10 vascular surgeons to further explore themes. Thematic analysis with a deductive approach will be taken to draw conclusions from the data.

RESULTS
78 responses were received and saturation was met by completing the interviews. Outcome priorities were different for each clinical speciality. Surgeons considered the rates of primary wound healing inferior to transfemoral amputation, which some linked to the challenging surgical procedure of KDA. They were aware of some of the advantages that a long residuum can offer at early-stage rehabilitation, but few surgeons mentioned the prosthetic implications of KDA. In comparison, physiotherapists and prosthetists discussed the surgical implications of KDA and suggested why the surgical technique means KDA is uncommon.

Physiotherapists and prosthetists were concerned about the cosmetic appearance of KDA, and the importance of shared decision-making with the patient before opting for a KDA. They felt the functional advantages of the long end weight-bearing residuum outweighed the cosmetic drawbacks. Further analysis of interviews is ongoing.

DISCUSSION AND CONCLUSION
Overall, clinicians' opinion of KDA is divided. Some clinicians observe poor outcomes in terms of wound healing and patient satisfaction with their prosthesis, and recommend KDA only for bedbound patients, whereas others feel KDA is an excellent, underused procedure with many functional benefits. This conflicting opinion mirrors the inconsistent conclusions of previous quantitative studies[4,5,6]. This study also highlights a compartmentalised approach to amputation surgery and rehabilitation.

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1.3.3.e
The Development and Usability of the AMPREDICT Decision Support Tool: A Mixed Methods Study

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BACKGROUND
Amputation level decision making in patients with chronic limb threatening ischemia (CLTI) is challenging. Physicians rely on average risks rather than individual patient risks. This has resulted in significant variation in amputation levels across health systems, geographical regions, and time. Clinical decision support has been shown to enhance decision making and reduce decisional conflict among physicians and patients by allowing them to weigh their individual risks against their priorities; however, no decision support tools exist guiding the amputation level decision.

AIM
To translate the validated AMPREDICT prediction models[1-3] into an internationally available, web-based *decision support tool* that predicts 1-year postoperative risk of mortality, reamputation, and probability of achieving independent mobility at each major amputation level and test its usability and implementation.

METHOD
This was a mixed-methods study including data from the *AMPREDICT* prediction models,[1-3] input from an expert panel of physicians, and testing by Veteran's Health Administration physician end users. Previously validated prediction models were translated into the web based *AMPREDICT Decision Support Tool*. Usability of the tool was assessed using the Post-Study System Usability Questionnaire (PSSUQ; a 16-item scale with scores ranging from 1-7, where lower scores indicate greater usability) by 10 clinician end users from diverse specialties, sex, geography, and clinical experience. Think-aloud, semi-structured, qualitative interviews evaluated the *AMPREDICT Decision Support Tool's* look and feel, user-friendliness, readability, functionality, and potential implementation challenges.

RESULTS
The PSSUQ overall and subscale scores were highly favourable, with a mean *overall total score* of 1.57 (SD=.69) and a range from 1.00-3.21. The potential clinical utility of the DST based on qualitative interviews included: (1) assistance in counselling patients on amputation level decisions, (2) setting outcome expectations, and (3) use as a tool in the academic environment to facilitate understanding of factors that contribute to various outcome risks. This presentation will include a live demonstration of the tool.

DISCUSSION AND CONCLUSION
Currently, available evidence on amputation level decision making in patients with CLTI relies on published average population risks rather than individual patient risks. After extensive iterative development and testing, the *AMPREDICT Decision Support Tool* was found to demonstrate strong usability characteristics and clinical relevance. Further development will benefit from integration into an electronic health record with assessment of its impact on physician and patient shared amputation level decision making outcomes.

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Free Paper Session
Prosthetics: Lower Limb – Sockets 1

1.4.1.a
Testing of Smart Adaptive Prosthetic Socket Volume: A Pilot Study

Natalie Harold[1], Aizen Ulric[1], Michael Carroll[2,3], M. Jason Highsmith[4,5], David Boone[1]

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BACKGROUND
Users with limb loss have prioritized socket fit and comfort above desires for other advanced prosthetic technologies (e.g., carbon fibre energy storing feet, microprocessor-controlled prosthetic components) [1]. Without a comfortable, well-fitting socket, the increased activity levels made available by other technologies cannot be achieved. Changes in residual limb volume and shape lead to difficulty maintaining a comfortable fit of a rigid prosthetic socket [2,3], negatively influencing limb health, and reducing the user's ability to successfully ambulate with the prosthesis.

AIM
To develop and evaluate a novel automated volume compensating prosthesis and vacuum suspension system to operate in equilibrium with the users' residual limb in order to maintain an improved socket fit and increase patient comfort.

METHOD
The socket test system was developed utilizing embedded volume elements constructed from viscoelastic foam. A dual-purpose vacuum pump automatically accommodated the socket volume to changes in the residual limb and provided secure suspension of the prosthesis. Five participants with transtibial amputations were enrolled in the IRB-approved pilot study. Qualitative user feedback, Prosthesis Evaluation Questionnaire (PEQ) responses, and quantitative StepWatch activity monitor data were recorded over a period of three days for two prosthesis conditions (pre-existing standard socket system and volume compensating test system). Each subject served as their own control in a one-way repeated measures study design.

RESULTS
Daily step count for participants increased from an average of 2,117 (SD 1,261) with their pre-existing standard socket system to 2,515 (SD 1,520) with the test system; an increase of 397 steps per day on average. The test system also resulted in a positive correlation for average step rate, although this result is statistically insignificant. The data from the PEQ supported the qualitative findings as well as our hypothesis that the test system would have a positive effect on users' residual limb health (mean +14.8 points) and reduced pain (mean +15.3 points) for all study participants

DISCUSSION AND CONCLUSION
The results of this project highlighted the need for further refinement of the test system and demonstrated the potential for the positive effects that an automated volume compensating system could have on socket fit and patient comfort. Factors associated with improved socket comfort and potential for increased socket lifespan are of interest to clinicians considering the fitting of new or existing lower limb prosthesis users who experience daily limb volume change.

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1.4.1.b

A Micro-Controlled Auto-Adjusting Prosthetic Socket for People with Transtibial Amputation: Results from Take-Home Testing

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BACKGROUND

Socket fit is the most important clinical challenge faced by people with limb loss [1,2]. The effort needed to continually sense and manage socket fit can be mentally, physically and emotionally draining to a prosthesis user. Inability to maintain a proper fit can lead to residual limb injury. A socket that can automatically make appropriate adjustments to maintain fit may improve a patient's independence and quality of life.

AIM

The aim was to evaluate in an at-home environment a micro-controlled socket that adjusted motor-driven socket panels to maintain a consistent "sensed distance" between the limb and socket.

METHOD

Participants with transtibial amputation classified as K-level 2 and at least 18 months post-amputation were included. A laminated carbon-fibre socket was made for each participant with movable socket panels located anterior medial, anterior lateral and posterior. Sensors that measured distance to the residual limb were embedded in the socket wall. Participants first wore the socket at home for 1 week in Automatic mode, where a micro-controller moved the panels radially inward or outward to maintain a consistent distance when the user walked. They then wore the socket an additional week in Manual mode, using a phone app to manually operate the motors to make socket size adjustments.

RESULTS

Results from two participants demonstrated a wider distribution of panel positions for Automatic mode than Manual mode during walking (Fig. 1). Participant #1 praised the Automatic mode and almost never overrode the controller. His socket comfort score (SCS) ranged from 7 to 9 in Automatic mode and 5 to 8 in Manual mode. Participant #2 made more adjustments when in Automatic mode than Manual mode, and on two occasions felt that the socket was too tight. He rated SCS 8 for both modes.

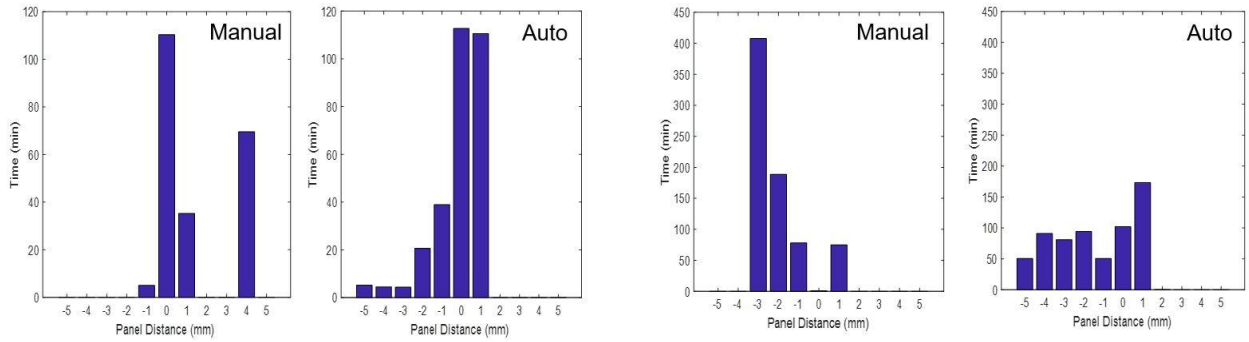

Figure 1. Total time spent at different socket sizes. Data from Participants #1 (left) and #2 (right).

DISCUSSION AND CONCLUSION

Results from this study demonstrated a functional auto-adjusting socket in users' at-home settings. Because the controller enlarged the socket when the residual limb gained volume, sockets in Automatic mode had a wider distribution of panel positions than when in Manual mode. A next step is to compare users' activity and socket fit differences for both modes over the course of the day.

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ACKNOWLEDGEMENTS: Supported by US Army Medical Research Acquisition Activity, contract #W81XWH-16-C-0020.

1.4.1.c

A Motor-Driven Release/Relock Socket: Effectiveness as an Accommodation Tool for Transtibial Prosthesis Users

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BACKGROUND

Residual limb volume loss during the day is a common problem for people who use a transtibial prosthesis. Relieving socket pressures during sitting (partial doffing) may help stabilize limb volume, but people who are active may not have time during the day to repeatedly remove clothing to doff and re-don their socket. A motor-driven system to allow for quick and easy locking pin and socket panel release during sitting and relock upon standing was developed to overcome this issue [1].

AIM

The aim of this study was to test if socket release/relock executed between bouts of walking increased limb fluid volume more than no release.

METHOD

Participants with transtibial amputation classified as K-level 2 and at least 18 months post-amputation were included. Test prostheses were fabricated with a motor-driven, locking-pin release/relock mechanism housed within the socket [1] and a cabled-panel mechanism within the socket wall. Limb fluid volume was continuously monitored using biompedance analysis [2]. Participants conducted repeated cycles of walking on a treadmill (2 min) and sitting with the socket donned (10 min, Control), or with the locking pin and panels released (4 min Short Rest, 10 min Long Rest).

RESULTS

Twelve people participated in the study. For shared time points across the three conditions (Fig. 1), a repeated measures ANOVA, with post hoc paired t-tests, demonstrated that limb fluid volume differences were significantly greater ($p<0.05$) for short rest vs. control and long-rest v. control. Only the 56 min time point was significantly greater for short rest vs. long rest.

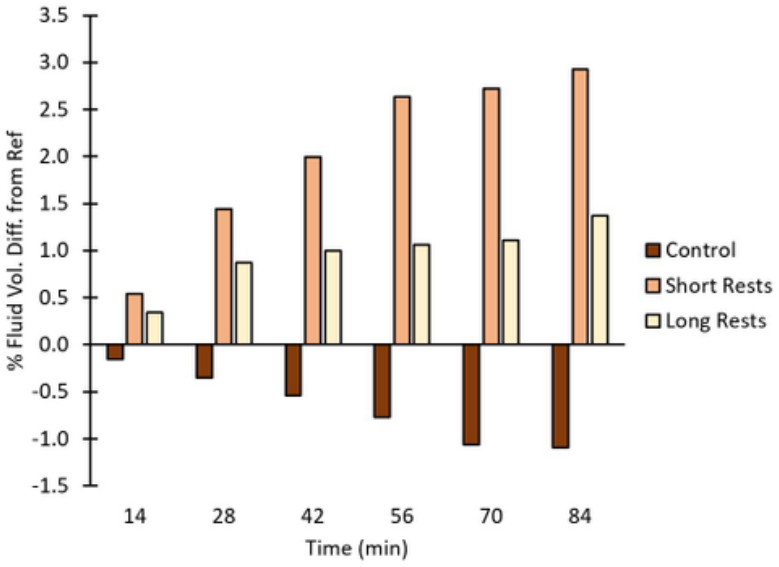

Figure 1. Percent fluid volume difference over time for Control, Short Rest (4 min), and Long Rest (10 min) conditions.

DISCUSSION AND CONCLUSION

Locking pin and socket panel release/relock may be an effective means to facilitate volume recovery in transtibial prosthesis users who would otherwise experience limb volume loss during the day.

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1.4.1.d

The Use of Artificial Intelligence to Predict Modifications on the Residual Limb Model in the Design of Transtibial Prosthetic Sockets

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BACKGROUND
Additive manufacturing is increasingly considered as a production technique to fabricate patient-specific prosthetic sockets. An important benefit of this production process is a complete digital workflow which is less time consuming compared to the traditional process of using plaster casting for mould creation and the modifications afterwards. To further increase time benefits of the digital workflow, we propose the use of artificial intelligence (AI) to predict required digital modifications at the residual limb.

AIM
This study aims to facilitate the digital modification process for transtibial prosthetic sockets. It uses machine learning techniques to predict the needed digital modifications based on a 3D-scan of the residual limb.

METHOD
In order to create a model to predict socket modifications, we collect a training dataset consisting of 3D-scanned stumps (with liner), questionnaires (including data such as liner type, patient's body mass, height, activity level, and sensitive spots on the stump) and 3D-scans of the modified positive plaster model. The dataset is obtained at five different orthopedic companies during the conventional manufacturing process of new prosthetic sockets. Exclusion criteria are non-healed wounds on the stump, patients aged <18, congenital amputations, and outliers based on stump shape. We create and compare different machine learning models (such as RegressorChain, ElasticNet regression and ExtraTreeRegressor).

RESULTS
Preliminary results, based on a dataset of 24 patients, show that the predictions of the different AI models are in line with the modifications of the prosthetists in the traditional process, however, less pronounced. Typical modifications (at patellar tendon, along tibial crest, distal tibia end, fibula head, muscles medial, lateral and dorsal) demonstrate the best predictions. Atypical modifications (such as around medial and lateral condyles, and sensitive areas due to scar tissue or painful spots) are, as expected, not yet captured in the model. The model yielding best results (ExtraTreeRegressor) predicts the modifications with a mean error of 1.36 mm.

DISCUSSION AND CONCLUSION
Preliminary results show that typical socket modifications can be predicted. We expect more input data to further lower the error. Atypical socket modifications are expected to be less accurate to predict by the model as they depend very much on a prosthetist's experience and patient specific characteristics.

ACKNOWLEDGEMENTS: We want to acknowledge VLAIO (Flanders Innovation & Entrepreneurship) and Orthobroker BV for financing this project, and the five involved orthopaedic companies for their cooperation.

1.4.1.e
Prosthetic Mechanobiology - How Using a Prosthesis Can Lead to Deep Tissue Injuries

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BACKGROUND
Deep Tissue Injury (DTI) is a form of pressure ulcer that forms when soft tissues experience prolonged or high pressure and shear. Our understanding of this condition increased significantly over the last two decades, with major research on immobilised individuals. However, transtibial prosthetic users might also be at risk of developing DTI: Following amputation, the soft tissues of the residuum become part of the weight-bearing system, despite being inapt to withstand high loads.

AIM
To understand DTI development in prosthetic users and identify gaps in existing research, we carried out a scoping review with a focus on population-specific aetiology, risk factors and methodologies to investigate both.

METHOD
The scoping review followed a methodological framework by the Joanna Briggs Institute [1], in compliance with the PRISMA-ScR checklist for scoping reviews [2]. Qualitative data was collected based on keywords related to transtibial prosthetic use in combination with DTI development. The database search in PubMed, Ovid Excerpta Medica, and Scopus, together with reference lists and forward-citations returned 16 peer reviewed, English language studies.

RESULTS
We addressed three key areas: Firstly, the aetiology of DTI is a complex interplay between cellular deformation and the impairment of lymphatic and microvascular systems. However, the influence of prosthesis-specific aspects like dynamic loading and amputation-related alterations of the ancillary systems remain unclear.

Secondly, we found several risk factors that make transtibial prosthetic users susceptible to DTI. Intrinsic determinants are amputation-related changes of the tissue morphology and its mechanical properties, and sensory impairment of the residuum. Extrinsic factors are the socket design and choice of prosthetic components.

Finally, the methodology of most studies was based on biomechanics. They commonly combined different loading conditions with medical imaging and computational analysis. However, we found a great variety of input data, modelling assumptions, and outcome measures. Additionally, the variability in geometrical patient characteristics and prosthetic componentry was high.

DISCUSSION AND CONCLUSION
The results indicate that transtibial prosthetic users may be at risk of DTI, depending on a complex interplay of mechanical, anatomical, and physiological factors. However, fundamental research on the reaction of cells, tissues, and ancillary systems to mechanical loading is needed. Additionally, high inter-patient variability and methodological limitations complicate the interpretation of outcome measures. We therefore recommend interdisciplinary research to widen our understanding of DTI in transtibial prosthetic users, which has the potential to initiate advances in prosthetic practice.

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Symposium
Developing Countries

1.4.2

Conducting Worthwhile P&O Research in Low-Resource Settings: What Constitutes Useful Data? A Data-Driven Approach to Drive Stakeholder-Defined Impact

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Abstract
The global need for P&O devices is well-established, as is the shortfall in service access, estimated at ~90% (WHO), especially in lower and middle income countries. We acknowledge a need to support evidence-based service provision, and measure research efforts on technology and service-provision innovations. Further, there is a need for “foundational datasets to inform the investment case for prosthetic services and the development of standards” (AT2030, 2020), but no clear consensus on what constitutes a good outcome of rehabilitation technology research, and what links technologies to social impacts. Following our Instructional Course on ethical, sustainably-translatable research, we will present a discussion of P&O data research:

- Clinicians’ and service providers’ needs: what is a good outcome of rehabilitation technology research projects? How do we plan for and measure translation?
- An assessment of the differences in service provision between settings, asking why successful technologies or programmes adapted into new countries or settings will not necessarily deliver the same outcomes. This justifies the need to create context-aligned bodies of research and outcome measures; and
- A series of situation analyses using datasets from across 17 countries of conflict and/or low resources, to illustrate potential data analysis approaches, assessment of service access, device longevity, correlation with social and political events, reasons for attendance, demographics inc. inequalities, approaching behavioural change, and the challenges in conducting such research.

We will address the different contexts of data collection and use in our case-study countries, and poll the audience throughout, to work towards a consensus report.

Statement of the learning objectives
This symposium will benefit clinicians and service providers defining their needs from research data, engineers matching their technology developments to real-world needs, and service users, to whom the research data belong.

Free Paper Session
Gait and Balance: Gait Analysis

1.4.3.a
Accuracy of Leg Kinematics in Estimating Key Gait Events for Amputees

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BACKGROUND
Key gait events (Heel Strike (HS) and Toe-off (TO)) help in determining important spatiotemporal gait parameters, such as speed, swing length etc. Clinically, these aid in the quantification of rehabilitation interventions for individuals with amputations. Force plates are used as a gold standard for their estimation. A simpler and low-cost, alternative is the kinematic gait data using gyroscopes. However, the accuracy of this data in predicting the events for amputees is not established in the literature.

AIM
To evaluate the accuracy of kinematic gait data (lower-leg velocity signal) for the calculation of gait events against the kinetic data from the force plate, latter being used as a gold standard.

METHOD
An open dataset [1] consisting of marker data from 10 Vicon cameras and force data from an instrumented treadmill is used. 18 subjects walked at 5 different speeds ranging from 0.4m/s to 1.4m/s. 10 subjects not using handrails are included in this study (239 trials with 2595 walking cycles). Angular velocity of the lower leg segment is calculated using the tibia-mounted markers using Winters' equations [2]. Actual toe-off (aTO) and actual heel-strike (aHS) events are marked using the force-plate data in [1] with a threshold of 20N for each gait cycle. The predicted events (pTO and pHS) are calculated using a rule-based algorithm similar to [3] in Matlab.

RESULTS
The error (eTO and eHS) is calculated by taking the difference between the predicted and actual events and its five-number summary is plotted in Figure 1. The largest error was found for TO event on the contralateral (sound) side with a median of 84ms and an IQR of ~24ms for all trials. The magnitudes of this error appeared to decrease progressively with increasing speed (median of 108ms at 0.4m/s vs. median of 74ms at 1.4m/s, Fig. 1). On the other hand, the median error eHS was smaller than eTO on both contralateral and ipsilateral sides.

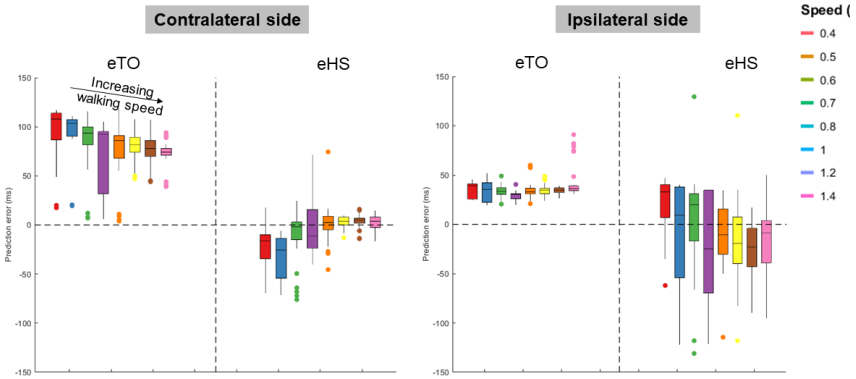

Figure 1. Boxplots for prediction error for both events (TO and HS) separated by side and walking speed

DISCUSSION AND CONCLUSION
These results indicate that the leg velocity signal could be used to estimate the HS event for amputees with median error well below 50ms in most cases. This implies that an accurate prediction of certain temporal parameters such as cycle duration and cadence is possible using this data. However, other temporal parameters such as stance and swing durations could contain larger errors due to involvement of TO. We plan to incorporate other leg kinematic variables to improve TO accuracy.

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1.4.3.b

Foot Strike Classification Using Smartphone Sensor Signals in Lower Extremity Amputee Population

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BACKGROUND

Today's smartphones contain built-in sensors that can be used to identify the user's foot strikes (FS) during walking. Proper FS identification can inform gait pattern, health, and mobility status. However, people with lower extremity (LE) amputation can present with asymmetric and variable gait [1]. These irregularities can lead to poor FS detection accuracy.

AIM

This paper presents a novel foot strike classification approach for the amputee population using smartphone sensor signals in a modified Long Short-Term Memory (LSTM) deep learning approach.

METHOD

The model was developed using retrospective data. Seventy-eight trans-femoral, trans-tibial, and bilateral lower limb amputees were recruited from the University Rehabilitation Institute (Ljubljana, Slovenia). An Android smartphone was placed on the lower back of each participant before completing a 6-minute walk test (6MWT) along a 20m hallway. The TOHRC Walk Test app [2] collected accelerometer and gyroscope signals at 50 Hz. Pre-processing was completed in MATLAB 2020. Ground truth steps were labelled by two assistants prior to training. LSTM deep learning models were written and evaluated in Python. Hyperparameter combinations were evaluated, including batch size (32, 64, 128), number of hidden LSTM and hidden dense nodes (25, 50, 75, 100).

RESULTS

The dataset had two class labels, label 0 represented "no foot strike present/detected" and label 1 represented "foot strike present/detected". 5-fold cross-validation was implemented to minimize over-fitting. Only participants who completed the full 6MWT trials were included. A total of 41,606 steps were identified and labelled in the ground truth data, accounting for 2.96% of all output labels (1,407,822). The overall accuracy of foot strike classification was 1.23%. Sensitivity was 29.1% and specificity was 72.3%.

	True Class 0	True Class 1
Predicted Class 0	969083	29450
Predicted Class 1	371551	12077

Table 1. Confusion Matrix

DISCUSSION AND CONCLUSION

This research used signals from integrated smartphone sensors to train a deep learning model. The results did not support this approach for foot strike identification. Model types that were successful for foot strike detection in other populations [3,4] could be considered as well as algorithms that were successful for people with lower-limb prostheses [5]. While often identified as a potential approach for movement classification, Long Short-term Memory classier did not achieve acceptable results with lower limb amputee gait signals.

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ACKNOWLEDGEMENTS: Research supported by NSERC (CREATE-READi). We acknowledge the contributions of physiotherapists and physicians at the University Rehabilitation Institute, Slovenia.

1.4.3.c
Do Assistive Devices Change Gait Parameters in Dementia?

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BACKGROUND
The use of assistive devices for gait helps the elderly with gait disturbances maintain daily activities and mobility (1). Using these devices requires a high level of motor control and appropriate motor patterns to the conditions can also be challenging for cognitive function (1). In dementia where cognitive problems are predominant, gait disturbances are also common (2,3). Considering the decline in cognitive functions, assistive devices for walking may have some effects on gait.

AIM
The aim of this study is to compare the spatiotemporal parameters and pelvic parameters during gait in individuals with dementia who use and do not use assistive devices for gait.

METHOD
The study included 27 individuals with dementia over the age of 65, having Mini Mental State Examination 18-23 score, walking independently with/without a single point cane, and staying in a nursing home. Participants were divided into two groups as Group-1 who use a cane and Group-2 who do not use a cane. The spatiotemporal parameters of gait and pelvic parameters were evaluated with the BTS G-Walk gait analysis sensor. Depending on the distribution of the variables, the two groups were compared using the independent samples t-test and the Mann-Whitney U test. All statistical calculations and analyses were performed with the IBM SPSS Statistics 22.0 program.

RESULTS
A total of 27 individuals, 12 individuals (85.0 ± 6.18 years, BMI = 26.24 ± 4.11 kg / m2) in Group-1 and 15 individuals (79.87 ± 8.04 years, BMI = 25.40 ± 4.28 kg / m2) in Group-2, participated in the study. There was no significant difference between the groups in terms of Mini Mental State Examination score ($p = 0.622$). The anterior tilt ($p = 0.02$), right lateral tilt (frontal) ($p = 0.042$), the gait cycle time ($p = 0.014$) and cadence ($p = 0.012$) was significantly different between the groups. No difference was observed between the groups in terms of other parameters examined.

DISCUSSION AND CONCLUSION
As a result of our study, it was observed that the degree of anterior tilt was higher and the degree of right lateral tilt, the gait cycle time, and cadence were lower in individuals using a cane. Although there were some differences, gait of the groups were similar. There is a need for larger studies on the use of assistive devices in individuals with dementia who are highly disadvantaged in terms of falls.

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1.4.3.d

Biomechanical Differences Between Able-Bodied Slow Walking and Spinal Cord Injured Individuals Walking in an Overground Robotic Exoskeleton

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BACKGROUND

Spinal cord injury often leads to wheelchair use. Lower limb robotic exoskeletons (LEXOs) have been designed to facilitate gait rehabilitation and ambulation. These devices generate slow speeds, more closely resembling gait with neurological impairments, than normal walking. Comparing the gait of LEXO users to normal walking could lead to unreasonable goal-setting. Therefore, understanding LEXO-gait compared to the slow gait of able-bodied individuals may inform practitioners on the properties of LEXOs.

AIM

To assess whether biomechanical differences exist between able-bodied slow walking (SLOW) and LEXO-gait of SCI users. The ReWalk™ LEXO was used, providing external support via articulated rigid segments around the lower limbs and pelvis, during overground walking with elbow crutches.

METHOD

Four spinal cord injured, experienced ReWalk™ users, (mean [SD]: age 36[11] years) walked along a 12-meter walkway with two force-plates (1000 Hz). Eight able-bodied individuals (mean [SD]: age 28[6] years) also walked along the 12-metre walkway at a slow speed (<0.45m/s based on pre-established LEXO gait speeds). Three-dimensional body kinematics (100 Hz) inside the device were captured using a modified six degrees-of-freedom marker set [1]. Sagittal joint kinematics were determined for normal and overground walking with the LEXO along with temporal-spatial parameters and ground reaction forces (GRF). Independent t-tests were used to compare the conditions (P<0.05) with standardised effect size reported as Hedge's g.

Table 1. Mean (SD) temporal-spatial, sagittal range of motion and ground reaction force values for SLOW able-bodied gait and LEXO gait. (Independent t-test, significance set at 95% and Hedge's g effect sizes)

	SLOW gait (SD)	LEXO gait (SD)	Significance (P)	Effect Size (g)
Temporal-spatial				
Speed (m/s)	0.43 (0.03)	0.32 (0.02)	>0.001	0.14
Step length (% leg length)	58 (6)	45 (1)	>0.001	17.57
Sagittal ROM				
Trunk (°)	5.8 (1.2)	20.6 (4.1)	0.008	12.57
Pelvis (°)	4.4 (0.8)	16.5 (1.0)	>0.001	11.39
Hip (°)	32.2 (3.1)	33.2 (2.8)	0.620	1.71
Knee (°)	53.3 (3.9)	44.8 (4.1)	0.028	24.46
Ankle (°)	28.7 (4.9)	18.6 (4.2)	0.013	20.39
GRF				
A-P braking (N/kg)	0.06 (0.0)	0.07 (0.0)	>0.001	0.09
A-P propulsion (N/kg)	0.10 (0.0)	0.14 (0.0)	>0.001	0.03

ROM: range of motion, GRF: ground reaction force, LEXO: lower-limb robotic exoskeleton, A-P: anterior - posterior

RESULTS

Step-length, cadence and step-width all presented as greater during SLOW compared with the LEXO gait (P = ≤0.01) contributing to the faster speed of the SLOW group. There were, however, no significant differences between groups for the temporal components (swing and stance time) (P ≥0.05). LEXO gait resulted in reduced knee and ankle sagittal plane range of motion (ROM), and with very large effect sizes, compared with SLOW; however, the hip ROM was not significantly different. Both the pelvis and trunk excursions in the LEXO group were significantly greater than in the SLOW group, 12.1° and 14.8° respectively (P ≤0.01). The anterior-posterior GRF was significantly greater in LEXO gait than SLOW walking in both breaking and propulsion phases (P = <0.01).

DISCUSSION AND CONCLUSION

Stepping in the LEXO is triggered by anterior orientation of a tilt sensor. The increased upper-body trunk excursions in LEXO gait may have resulted in earlier anterior lean and reduced ground clearance. This leads to earlier ground contact and reduced step-length. The LEXO's programming ensures that full ROM is achieved at each joint for each step. Consequently, the LEXO would have pushed the body backwards to achieve full hip flexion. This could have led to the increased braking force.

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ACKNOWLEDGEMENTS: We would like to thank Cyclone Mobility limited for the use of the ReWalk™ exoskeleton.

1.4.3.e
Evaluation of a Smart Hallway Multi-Camera System

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BACKGROUND
Marker-less motion analysis provides a non-invasive method for studying human movement, since movement is measured without markers or other sensors on the body. Institutional hallways could be ideal locations for autonomous collection of movement data. This Smart Hallway could have multiple cameras affixed to the ceiling and an artificial intelligence model used for joint location identification from video [1]. Research is needed to determine the clinical viability of such a system.

AIM
Design and validate a marker-less human motion analysis approach for institutional hallways.

METHOD
An institutional hallway setting was computer-modelled to determine camera placement based on 5 and 10 m capture volumes and to provide support for hardware selection. Camera layouts were tested based on hallway dimensions and useable volume calculated through camera view intersections. Artificial intelligence models were selected based on output data quality obtained by applying the model to videos containing clinically relevant movements. After configuring hardware and developing software, the system was validated through camera synchronization testing, calibration testing, stride parameter measurements, and limb length measurements. Pilot trials were performed with a participant walking through the capture volume and the participant's limb lengths were measured for ground truth comparison data.

RESULTS
Modelling showed that a four-camera layout could accommodate a 5 m walking distance and 25 m^3 capture volume within institutional hallway dimensions. An eight-camera setup was also verified to expand the volume to 10 m distance. The OpenPose BODY25 model [1] was selected for marker-less joint keypoint inference based on better performance compared to HyperPose COCOv2 [2] on the set of clinical videos ($p<0.001$). Various algorithms were introduced to improve joint location data quality from the AI model. Camera synchronization was quantified, and all cameras remained within 5 µs after capturing multiple images. The multi-camera system was calibrated to a pixel reprojection error of less than 0.2 pixels. Preliminary tests regarding limb lengths were within 3.545+/-0.036 cm (10%) of measured limb lengths; foot strike and foot off times were within 0.095+/-0.045 s of measured event times.

DISCUSSION AND CONCLUSION
A Smart Hallway that uses artificial intelligence-based marker-less human movement analysis provides a viable method for assessing a person's motion. By utilizing previously unused space in an institutional hallway and non-intrusive autonomous processes, quantitative assessment of movement can be brought more easily into care at the point of patient contact. Also, AI-based movement assessment could occur as people walk through a hallway to provide regular knowledge of patient progression or elderly-care regression.

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ACKNOWLEDGEMENTS: Funded by NSERC (Discovery, CREATE-BEST, CREATE READi programs).

Free Paper Session
Prosthetics: Lower Limb – Gait Biomechanics and Energy

1.5.1.a

General Estimates of the Energy Cost of Walking in People After Lower Limb Amputation: A Systematic Review and Meta-Analysis

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BACKGROUND

Energy cost of walking (ECw) is an important determinant of walking ability in people after lower limb amputation [1]. It has frequently been found that people after lower limb amputation have increased ECw compared to able-bodied individuals [2,3]. However, large variety in estimates of ECw are reported in literature, which is likely related to the heterogeneity of this population in terms of level and cause of amputation and related physical conditions that affect walking ability and walking speed.

AIM

To provide quantitative estimates of differences in ECw between people after lower limb amputation and able-bodied controls, taking into account the influence of cause of amputation, level of amputation and walking speed.

METHOD

We searched PubMed, CINAHL and PEDro for studies (published until March 2020) that compared ECw in people after lower limb amputation to an able-bodied control group. Through a meta-analysis we investigated the change in ECw after amputation, and possible influence of level and cause of amputation. In a second analysis, we included all articles with and without an able-bodied control group to investigate the effect of self-selected walking speed on ECw.

RESULTS

Out of 526 identified articles, 25 were included in the meta-analysis and an additional 30 in the walking speed analysis. The meta-analysis showed that people after lower limb amputation have significantly higher ECw compared to able-bodied controls (35%, p<0.00001). Cause and level of amputation had a significant influence on ECw (*p*<0.00001). On average, the increase in ECw is largest in people with a transfemoral amputation due to vascular reasons (102%), followed by non-vascular transfemoral amputation (41%), vascular transtibial amputation (36%) and lowest after non-vascular transtibial amputation (12%). Furthermore, self-selected walking speed had a major effect on the ECw, with lower walking speeds resulting in increasing ECw.

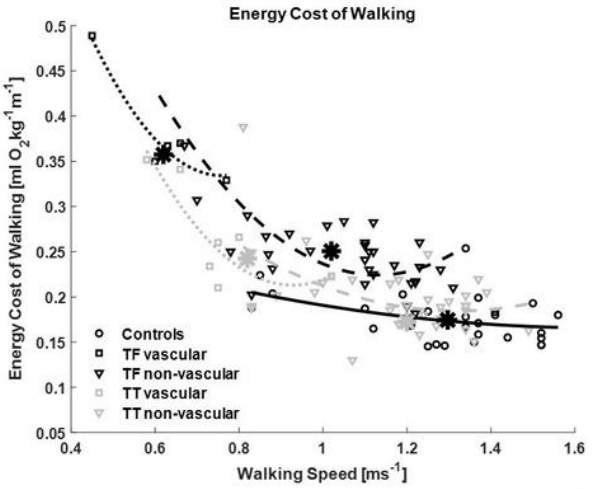

Figure 1. The relationship between ECw and walking speed for four subgroups of people with an amputation and an able-bodied control group. TF = transfemoral; TT = transtibial.

DISCUSSION AND CONCLUSION

People with a lower limb amputation show a considerable increase in ECw. Estimates vary between 12-102%, depending on level and cause of amputation and walking speed. Variability within subgroups appeared to be considerable, due to differences in study conditions, and especially by differences in walking speed between persons. The results of this study can be used in clinical practice to set patient-specific expectations for ECw and to develop and evaluate interventions to reduce physical strain in this patient group.

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1.5.1.b

Effects of Walking Speed on External Mechanical Work on the Body Centre of Mass in Transfemoral Prosthesis Users

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BACKGROUND

During human locomotion, each limb performs step-to-step work on the body centre of mass (BCoM) to maintain forward ambulation [1]. This efficient energy exchange involves alternating periods of negative and positive work that rely on physiological mechanisms to support limb collision and push-off at initial contact and terminal stance, respectively. Such mechanisms are altered or impaired in transfemoral prosthesis users (TFPUs) relative to able-bodied ambulators, which might explain their noted asymmetry and increased metabolic cost [2].

AIM

To characterize the effects of walking speed on individual-limb BCoM work in unilateral TFPUs to gain insight into gait compensations and means for improving gait efficiency.

METHOD

Twenty-five unilateral TFPUs (19M, 6F, 31±10yrs, 166±7cm, 65.6±13.9kg) wearing their customary prosthesis (n=15mechanical, n=10microprocessor knee) walked on a split-belt instrumented treadmill (TecGihan Inc., Japan) that collected instantaneous ground reaction forces (GRFs) at 1000Hz. Participants walked 7mins to accommodate to the treadmill then at 8 speeds (0.55-1.53m/s with 0.14m/s increments) for 30sec each. GRF data was processed in MATLAB (Mathworks, USA) using the Individual Limbs Method [1] to calculate work (J/kg) for each limb over three phases of a step: collision (first double support), midstance (single support), and push-off (second double support). ANOVAs assessed the main effect of speed and limb on work for each phase (α=0.05).

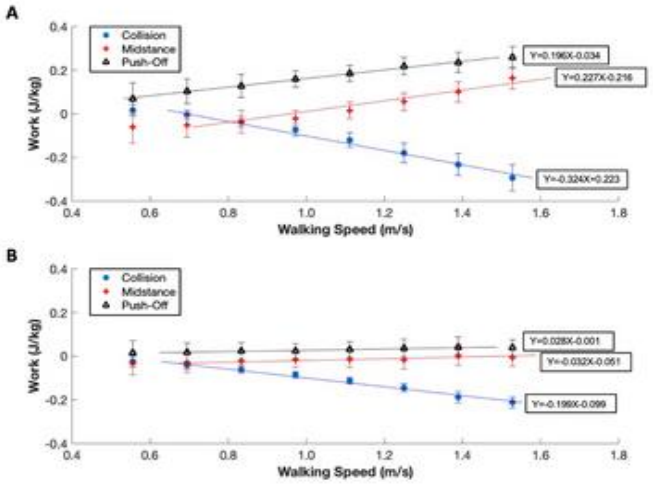

Figure 1: Mean work at each speed for (A) sound and (B) prosthetic limbs. Error bars represent 95% confidence interval. Fit lines and equations are included to visualize speed trends.

RESULTS

Figure 1 displays collision, midstance, and push-off work for both limbs at each speed averaged across participants. TFPUs display an increase in collision work with walking speed on both limbs. Midstance work for the prosthetic limb remains nearly unchanged across speeds, but increases almost exponentially on the sound limb after 1.11m/s suggesting that positive work is being maximized through mid and late stance on this limb to compensate for greater sound limb collision work. The sound limb always produced greater push-off work than the prosthetic limb. While nearly equivalent across speed, there was a small increase in prosthetic limb push-off work after 1.11m/s possibly due to greater energy return from the prosthetic foot. Secondary statistical analysis revealed a significant effect of prosthetic knee type on sound limb collision work with microprocessor knees corresponding to less work at equivalent walking speeds.

DISCUSSION AND CONCLUSION

Results suggest that TFPU gait inefficiency may be related to a near complete absence of prosthetic limb work generation, relying more on the sound limb to drive energy changes. The heavy reliance on the sound limb indicates the need for additional attention to the potential long term effects on health of the sound limb. Future work should focus on individual muscle contributions to determine the physiological mechanisms used to compensate for minimal prosthetic limb power generation.

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1.5.1.c

The Impact of Transfemoral Socket Adduction on Pelvic and Trunk Stabilization During Level Walking – a Biomechanical Study

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BACKGROUND

As a result of a transfemoral amputation, several muscle insertions of the hip adductors – depending on residual limb length – are lost, while hip abductors remain mostly intact. This leads to a muscle imbalance between these muscle groups[1]. It is known from common practice, that transfemoral prosthetic sockets should be aligned in adduction, to recover the physiological pretension of the hip abductors best possible[2,3]. This contributes to pelvic stabilization in frontal plane and reduces compensatory movements of the pelvis and trunk.

AIM

The aim of this interventional biomechanical study was investigating the impact of systematically different socket adduction positions on the pelvic and trunk stabilization during level ground walking.

METHOD

Four adduction conditions were investigated (0°, 3°, 6°, 9°). Seven active unilateral transfemoral amputees (K3 and K4 ambulators) with medium stump length (1/3 - 2/3 of the sound side thigh segment) participated in this study. Kinematic and kinetic parameters were recorded in a gait laboratory with a 12-camera optoelectronic system (Vicon, GB) and two piezoelectric force plates (Kistler, CH) embedded in a 12-m walkway. The measurements were performed during level ground walking with self-selected comfortable velocity.

RESULTS

Step width was larger with increasing socket adduction. This is a result of positioning the shank-segment of the prosthesis more laterally, indicated by the slightly more abducted thigh-segment. The medially directed ground reaction force was higher on both sides with increasing socket adduction, while external hip adduction moment was reduced on prosthetic side. The pelvis was raised on the contralateral side over the whole gait cycle with increasing socket adduction (Figure 1 A). During prosthetic side stance phase shoulder obliquity and lateral trunk lean (Figure 1 B) to prosthetic side was reduced with increased socket adduction.

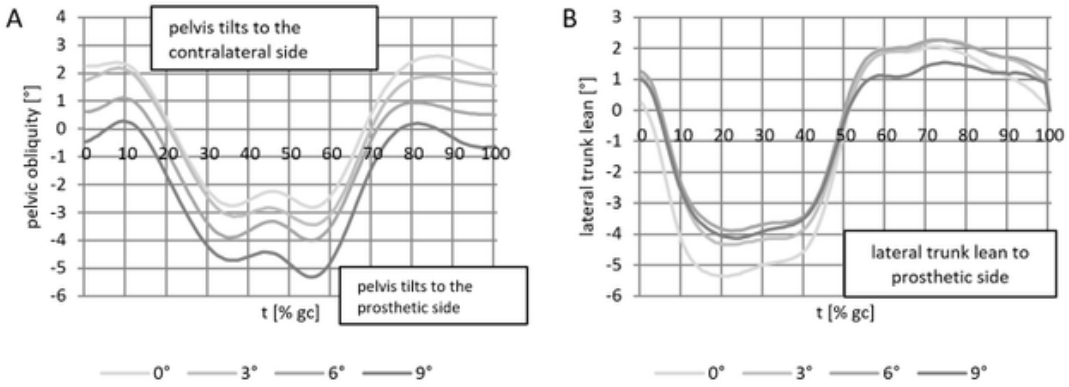

Figure 1. Mean pelvic obliquity (A) and mean lateral trunk lean (B)

DISCUSSION AND CONCLUSION

The results confirm, that transfemoral socket adduction contributes to pelvic stabilization and reduced compensatory movements of the pelvis and trunk. Socket adduction of 9° turned out to be too high in some cases for the investigated medium stump length. Thus, a socket adduction of 6±1° for bench alignment seems adequate for amputees with medium stump length. However, optimum is individual for every amputee and may differ slightly from these values.

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1.5.1.d

Biomechanical Characteristics of Transfemoral Prosthetic Gait Before and After Osseointegration Surgery

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BACKGROUND

Transfemoral socket prostheses can restore walking function after amputation, but gait deviations and socket instability are common and can lead to inefficiencies in walking. Osseointegration (OI) surgery creates a direct connection between the bone and the prosthesis, potentially improving control and reducing gait deviations. In addition to standard outcomes that show differences in prosthesis use and mobility scores after OI, an understanding of biomechanical changes can be assessed through instrumented gait analysis with temporal-spatial, kinematic, and kinetic data.

AIM

To compare the gait analysis before transfemoral OI surgery using a socket prosthesis, to 6 and 12 months after OI surgery to assess whether the gait pattern is more similar to that of healthy subjects.

METHOD

A case study of a 34-year-old female with left transfemoral amputation is presented. She was a high level ambulator (Amp Mobility Predictor 45/47) but having problems with socket tolerance for extended activities. Kinematics, kinetics, temporal-spatial, and EMG data were recorded by a motion analysis system at comfortable and fast walking speeds at baseline with a socket prosthesis, and 6 and 12 months after OI surgery with the same prosthetic components. Functional outcome measures were recorded at all time points.

RESULTS

Compared to baseline with the socket prosthesis, OI prosthesis walking was slower. At 12 months there was improvement in the right toe off time indicating better symmetry and more stability in stance. Trunk lateral lean and rotation improved to normal at 6 and 12 months compared to baseline. Anterior pelvic tilt increased at 12 months, but the total range of pelvic motion decreased at each time point. Pelvic obliquity showed left side hip hiking at baseline, which resolved at 6 months. Pelvic rotation at 12 months was more symmetric compared to baseline and 6 months. Loading profiles showed low moments at the hip and high power generation at the right ankle with minimal change. There was no change in mobility scores, but based on Questionnaire for Persons with Transfemoral Amputation (Q-TFA), problem score decreased and physical and mental health improved.

DISCUSSION AND CONCLUSION

The OI prosthesis improved symmetry and pelvic and trunk motion, reflecting effective hip abductor stabilization related to the direct skeletal control. Functional measures showed a ceiling effect. Satisfaction and perceived health improved. These results reflect a case study of a high-functioning individual. The gait analysis added to the understanding of the improvements after OI that were not reflected in typical assessment measures. Instrumented gait analysis can help researchers to understand additional potential benefits of OI.

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1.5.1.e

Oxygen Consumption and Gait Efficiency in Persons Using a Transfemoral Bone-Anchored Prosthesis Compared to Socket-Prosthesis Users: A Cross-Sectional Study

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BACKGROUND

A transfemoral bone-anchored prosthesis (BAP) is an alternative for the conventional socket-suspended prosthesis (SSP) in persons suffering from socket-related problems. Previous within-subject research showed that switching to a BAP improved oxygen consumption during walking [1,2]. It remains elusive whether this finding generalizes to SSP-users without socket-related problems. Hypothesised is that the fixed suspension of the BAP compared to the pistoning and instability during stance of a SSP improves the gait efficiency and subsequently oxygen consumption during walking.

AIM

To determine whether oxygen consumption and gait efficiency during walking differ between satisfied users of transfemoral SSP and BAP and able-bodied individuals (AB), and to identify differences in gait efficiency and pistoning as potential determinants of oxygen consumption.

METHOD

Three groups were included in the study: persons with a BAP (n=10), persons with a SSP (n=10), and AB (n=10). The prosthetic users did not experience prosthetic-related problems. For oxygen consumption measurements, participants walked on a treadmill three times four minutes (preferred speed, 30% slower, and 30% faster). Center of mass (CoM) efficiency [3] and root-mean-square values (RMS) of CoM in mediolateral (ML) and sagittal (S) directions evaluated the gait efficiency at preferred walking speed. Pistoning was calculated as the upper-leg shortening (ULS) in the early stance phase. Associations between oxygen consumption, gait efficiency, and pistoning at preferred walking speed were evaluated.

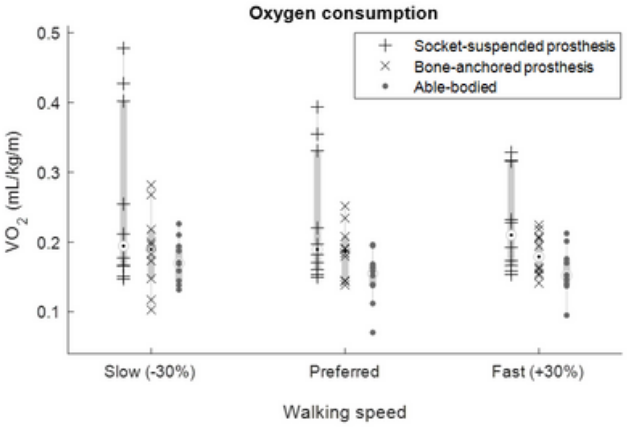

Figure 1: Oxygen consumption for the different walking speeds displayed for each group. Each data point represents one subject.

RESULTS

Preferred walking speeds were not significantly different between groups (BAP:0.90m/s, SSP:0.94m/s, AB:1.08m/s, p=.063). Oxygen consumption (Fig.1) was significantly higher in the SSP compared to the AB group (p=.026); the BAP group was not significantly different from the AB and SSP groups. CoM RMS ML was significantly higher for SSP (21.7mm) in comparison to AB (16.7mm, p=.041). No significant differences were found for CoM efficiency and CoM RMS S ULS was significantly larger for SSP (14.7mm) compared to BAP (3.1mm, p<.001) and AB (4.1mm, p=0.001). Lower CoM efficiency (ρ=.597, p=.001) and larger CoM RMS ML (ρ=.465, p=.001) were associated with higher oxygen consumption. Additionally, greater ULS was associated with larger CoM RMS ML (ρ=.381, p=.041).

DISCUSSION AND CONCLUSION

Results suggest no difference in oxygen consumption between BAP and satisfied SSP-users. Nevertheless, BAP-users do tend towards similar oxygen consumption as AB, in contrast to SSP-users. The fixed suspension of the BAP compared to the pistoning of SSP likely improves gait efficiency and subsequently the oxygen consumption during walking. These finding suggest probably a broader population could benefit from the BAP technology.

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Advanced Instructional Course
Orthotics: Lower Limb

1.5.2
Towards Novel Solutions for Ankle-Foot Orthotics Optimization in Clinical Practice

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Abstract
In many neuromuscular disorders calf muscle weakness progresses slowly over time, which leads to limitations in daily life by reducing walking speed, increasing walking energy cost and fatigue. To compensate for calf muscle weakness ankle-foot orthoses (AFOs) are often prescribed with the aim to augment walking. The effect of AFOs on improving gait biomechanics, speed and energy cost depends on their mechanical properties, especially AFO stiffness, and how these properties are matched with the patients' impairments. Consequently, to maximize the treatment effects of AFOs, the stiffness needs to be optimized for each individual user. We have coined this as Precision Orthotics. An opportunity of Precision Orthotics is that it may lead to improvement of treatment outcome, i.e. substantially benefitting walking ability for the individual patient. In this symposium, we will first demonstrate that in current orthotic care, AFO stiffness is often not optimally matched to the patient, which results in suboptimal treatment outcomes. Secondly, we demonstrate how AFO stiffness can be matched to the individual patient by experimental tests and instrumented gait analysis, and show the clinical benefits of such Precision Orthotics compared to AFOs prescribed in regular care. Lastly, we will discuss how Precision Orthotics can be implemented in usual care using state-of-the-art methods as human-in-the-loop optimization and predictive simulations.

Outline:
- Treatment with AFOs: clinical perspective (15 min)
- Stiffness optimization of AFOs to maximize treatment outcome (20 min)
- Implementation of Precision Orthotics in usual care (25 min)
- Plenary discussion (15 min)

Statement of the learning objectives
1) To provide a knowledge base of ankle-foot orthosis prescription in rehabilitation.
2) To provide knowledge-base of methods to match the AFO stiffness to the individual patient in clinical practice now and in the future.

Symposium
Device Fabrication and Design

1.5.3
Digital Transformation of Prosthetic and Orthotic Services

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Abstract
35–40 million people globally need prosthetic and orthotic (P&O) services, with the global need expected to double by 2050. WHO estimates that only 5–15% of the people who could benefit from assistive products have access to them. The traditional process of P&O provision requires a high degree of craft expertise and is labour and infrastructure-intensive. This model, while expert, is difficult to scale to meet the growing need.

Digital transformation (DT) of the manufacturing process could be one of the most promising methods to meet the growing need for P&O services. However, discussions continue within the P&O community about the potential opportunities for, and concerns about DT. When speaking of DT, we include all changes associated with the use of digital technologies. At a minimum these support the traditional working methods and at the extreme could completely disrupt the way devices are manufactured and services provided.

This symposium will share recent work undertaken by ISPO and GDI Hub to better understand the evidence for the challenges and opportunities of DT for manufacturing of prostheses and orthoses. We will share:

1. Literature review outcomes
   - Level of evidence for digital processes and products
   - Regional & product (e.g., lower, upper limb, spinal) differences
2. A global mapping exercise of P&O Digital Services and Methods
   - Interactive mapping – how and why useful
   - Initial insights from mapping
3. Expert insights captured from the clinicians, industry, developers, users

Statement of the learning objectives
An overview of the level of evidence for different digital products and processes that could transform P&O manufacturing. Highlights include major evidence gaps, potential barriers, case studies of successful digital practices.

Free Paper Session
Prosthetics: Lower Limb 1

1.6.1.a
Hemipelvectomy and Hip Disarticulation Prostheses: A Scoping Review

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BACKGROUND
Although the global population with hemipelvectomy (HP) or hip disarticulation (HD) is small compared to people with transfemoral or transtibial amputation, the degree of disability is much greater, with functional and independence concerns. People with an amputation at the hip or pelvis have the most difficulty returning to walking because their prosthesis must replace the hip, knee, and ankle joints. A comprehensive literature review is needed to examine the research surrounding prostheses for hip-level amputation.

AIM
To summarize available research that can enhance clinicians' understanding of hip disarticulation and hemipelvectomy prostheses.

METHOD
An electronic search was conducted to find HP or HD prosthesis-related research articles using Google Scholar, PubMed, Scopus, and Web of Science databases. The date range was 1950 to September 2020. Boolean searching techniques were used and search keywords were ("hip disarticulation" OR "hemipelvectomy") AND ("amputee") AND ("prosthesis" OR "artificial limb" OR "socket" OR "design"). Studies were included if they evaluated HD or HP prostheses (retrospectively or prospectively) and were written in English. Conference papers and theses were not included in this review. Study design and protocol, research instrument, sample size, and outcome measures were reviewed.

RESULTS
After removing duplicate articles and studies that did not meet the selection criteria, 53 articles were identified. The research evaluated effects of prostheses on people with HD (30 articles), HP (13 articles), both amputation levels (7 articles), and no amputation (3 articles). Most of the studies were performed in the USA (24) and Japan (9). Eighteen research articles had only one participant and 14 studies were case series with five or fewer participants. In 42 articles, authors prospectively evaluated a HD or HP prosthesis. On average, prospective studies had 4 (SD=5) participants. Since 1950, only five prospective studies evaluated HD or HP prostheses with 10 or more participants. Available articles in the literature evaluated one or more of the following items: outcome measure, socket design, energy expenditure, gait, hip joint design, pressure distribution, casting technique, and patient satisfaction.

DISCUSSION AND CONCLUSION
High-quality evidence is lacking on the effects of prosthetic components on gait, user satisfaction, prosthetic use, interface pressure, and energy expenditure. Authors mostly evaluated their new design or technique on one or two people with HD or HP amputation. Small sample sizes and insufficient information in the methodology of most articles limited confidence in their findings and generalizability to all patients. New research with vigorous methodology and larger sample sizes is needed to provide strong statistical conclusions.

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1.6.1.b
The Hip Disarticulation Prosthesis: Considerations on Rehabilitation

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BACKGROUND
Hip disarticulation is a rare procedure, usually performed for invasive tumours or other serious conditions for which limb conservation isn't possible. After disarticulation prosthetic fitting and prolonged rehabilitation are the next steps to improve the quality of life and functionality of these patients. However, despite efforts, only a small percentage of patients are able to walk with the prosthesis.

AIM
This work aims to identify the causes of patient drop-out from prosthesis rehabilitation and analyse the literature on the best rehabilitation approach for these patients.

METHOD
A comprehensive search of the available literature was performed using electronic databases (PubMed and Google Scholar) from origin until the current date. Keywords relevant to the question being studied were chosen (Hip disarticulation, Canadian-type prosthesis, rehabilitation). Boolean operators were used to narrow the search results. All relevant studies concerning rehabilitation after hip disarticulation were retrieved for analysis. Results are presented in a narrative format.

RESULTS
Available data is mostly based on small observational studies. Studies demonstrate that patients can achieve independent ambulation with a prosthesis albeit with higher energy expenditure and slower walking speeds. Patients also experience limitations in standing, sitting, and climbing stairs. Trunk stability appears to not differ compared to other types of amputation. A higher degree of fitness seems necessary to achieve successful ambulation. Rehabilitation programs should include cardiovascular training, ROM and strengthening exercises, training in transfers, daily activities, and walking. Socket discomfort, cosmetic reasons, and ambulation difficulties are the most common reasons for patient dropout. Age, body mass index, other comorbidities, and demographics weren't associated with unsuccessful prosthetic fitting. Outcomes appear better for hip disarticulation from tumour causes than those with vascular and infectious causes. According to a study, juvenile patients can easily master the disarticulation prosthesis and achieve a satisfactory gait.

DISCUSSION AND CONCLUSION
Independent ambulation after hip disarticulation is possible and depends on successful prosthesis fitting and intensive rehabilitation. Current evidence on this subject is limited. However, a program consisting of cardiovascular conditioning, joint mobility, global strengthening, daily activities, and walking training seems to be the basis of a successful rehabilitation program. Attention should be paid to socket revision until maximal comfort is achieved. An individual assessment of each patient's expectations and goals is also essential to improve outcomes.

1.6.1.c

Gait State Detection Based on Pelvic Motion of Transfemoral Amputees at Varying Gait Velocities

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BACKGROUND

Motorized prosthetic knee joints have many advantages over conventional prosthetics [1]. Hip prosthetics have yet to benefit from active robotics, partially due to the lack of lower limb movement to be used as a control source [2]. Gait state could be determined using pelvic obliquity angular motion [3]; however, reliance on a single-axis pelvic motion to control motorized hip prosthetic can be unreliable and prone to detection errors. Further research on the pelvic motion for gait state detection is needed.

AIM

To analyse pelvic rotation, tilt, and obliquity of 10 transfemoral amputees and extract common characteristics that can be used to design an intelligent hip prosthesis control system

METHOD

VICON motion-capture from 100 strides (ten strides for ten participants) were selected. 3D pelvic motion (tilt, obliquity, rotation) was extracted and studied separately. Initial foot strike and foot off angles, as well as angular velocity threshold crossing, were the focus since they provided information regarding local minima and maxima of pelvic angular displacement at each major gait state. The extracted points were then compared with hip angle, gait time, and gait velocity to determine correlations.

RESULTS

Four correlations were common among all participants: hip extension and the pelvic tilt angular displacements at max hip extension instance ($r = 0.67$), hip flexion angle and the pelvic tilt at heel strike ($r= 0.85$), second threshold crossings of pelvic rotation in relation to the hip angular displacement in that instance ($r = 0.49$), pelvic rotation angular displacement at the first threshold crossing of the swing phase, inversely correlated to the gait velocity ($r= -0.6$). The third and fourth correlations improved after removing data from participants 4 and 7 ($r= 0.63$ and $r= -0.82$, respectively). The individual analysis demonstrated that the second threshold crossing of pelvic rotation can be used as the reference point for detection of foot flat instance during stance phase ($r> 0.7$, present for 5 people).

DISCUSSION AND CONCLUSION

Many factors contribute to pelvic motion variability. This study determined that, although measurements of angular velocity threshold crossings can be utilized to extract features common among all participants, a separate analysis of each pelvic motion dimension did not yield more than 85% correlation. However, the combined use of extracted features from all three axes of pelvic motions could provide a reliable gait control system for motorized hip prosthetics.

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1.6.1.d

Differences in Self-Reported Mobility in Persons with Lower Limb Amputation Using Either a Microprocessor or Mechanical Knee-Joint

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BACKGROUND

Several factors affect the mobility of persons with a lower limb amputation (LLA), and for persons with a transfemoral amputation (TFA), type of prosthetic knee may be an important factor. Wurdeman [1] showed that TFA with microprocessor knee joints (MPK) had higher self-reported mobility than TFA with non-MPKs, but their study included persons with both dysvascular and non-vascular aetiology. Presently, there is little data on how the use of MPK or non-MPK affect self-reported mobility in TFA with non-vascular amputation.

AIM

Investigate the impact of using either a MPK or non-MPK on self-reported mobility of persons with non-vascular TFA

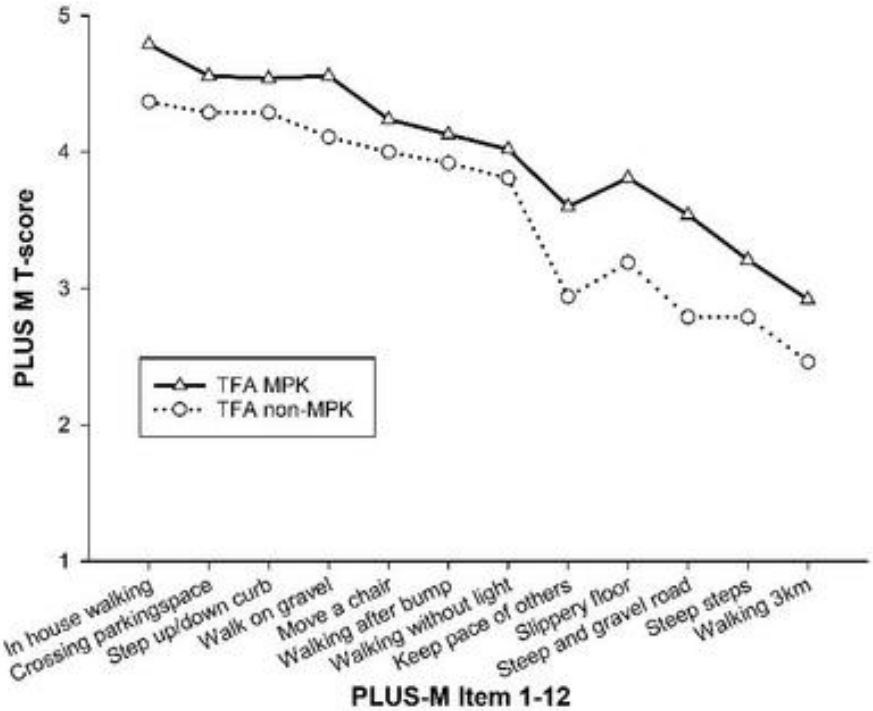
METHOD

Of a cohort of 465 persons in Norway with LLA, a sample of 115 persons (41 females) with non-vascular TFA were included in the present analysis. Self-reported mobility was reported by the 12-item Prosthetic Limb User Survey of Mobility (PLUS-M) [2]. Each item was scored from 1 to 5 (1=unable to do, 5=without any difficulty). In addition, information regarding age at amputation and years as prosthetic user was collected. Pairwise comparison of groups was done by Independent Samples T-test.

RESULTS

Mean (SD) age when amputated for TFA MPK (n=64) and TFA non-MPK (n=51) was similar between groups with 35.5 (19.5) and 31.6 (25.4) years, respectively. Experience as prosthetic user for the different groups were 18.3 (14.2) and 30.9 (21.0) years, respectively ($p<0.001$). Mean (SD) PLUS-M T-scores for TFA MPK, and TFA non-MPK was 54.7 (9.1), 50.7 (10.3), respectively ($p<0.05$). The average difference in T scores for MPK and non-MPK users across the different 12-items was 0.373 (95% Confidence Interval 0.040 – 0.707) (Fig 1).

Fig.1 Mean PLUS-M score for each of the 12 items of the PLUS-M questionnaire



DISCUSSION AND CONCLUSION

All participants were amputated at approximately the same age (~30-35 years) and of similar aetiology. Mean PLUS-M T scores were significantly higher for TFA MPK compared to non-MPK despite the fact that the non-MPK were significantly more experienced prosthetic users. The observed mean difference in T-Score is close to the minimum detectable change of 4.5 (90% CI), hence type of prosthetic knee may be important for over-all mobility of non-vascular TFA, but more research is needed.

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1.6.1.e

A Systematic Review of Electromyography-Driven Control Algorithms for Lower Limb Prostheses

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BACKGROUND
Most amputations occur in the lower limb but despite the availability of musculature in the residual limb and improvements in prosthetic technology, no commercial prosthetic legs use electromyographic (EMG) signals as input for control. Rather, commercially available prosthetic legs are completely passive or rely on information other than neuromuscular for controlling the prosthesis. Nevertheless, research on using EMG signals for lower limb prosthetic control has been conducted by different research groups around the world.

AIM
To provide a systematic review of the state-of-the-art algorithms utilizing EMG for the control of lower limbs.

METHOD
Four different online databases were searched in July 2020: Web of Science, Scopus, PubMed, and Science Direct. The search was conducted with the keywords: prosthetic OR prostheses OR prosthesis OR "artificial limb" AND (("lower limb") OR leg OR ankle OR knee) AND control AND (Electromyography OR EMG OR neural)). Only publications reporting the use of EMG signals from the lower limb for control of a leg prosthesis or for classification of ambulation or non-weight-bearing movement were considered. A total of 130 papers were included and assessed in this review.

RESULTS
More than 60 percent of studies included weight-bearing activities and able-bodied participants, with 2-16 electrodes placed over the residual gluteal muscles or residual shank muscles (transfemoral and transtibial amputation, respectively). In studies including individuals with transfemoral amputation, machine-learning-based methods such as linear discriminant analysis or support vector machine were most used for classification of lower limb movements (90 percent). Direct control was most popular in studies with individuals with transtibial amputation (85 percent). For the machine learning control methods, the most common outcome measure was error/accuracy of classification. Large variations were found across studies, for example, different control methodologies, research participants, recording protocols, assessments, and prosthetic hardware.

DISCUSSION AND CONCLUSION
Special consideration was given to studies in which real-time decoding of ambulation modes was performed on research participants with amputation. These papers are important since this condition better reflects home-use of a prosthesis. Machine learning was the most common method for classification. These algorithms are easy to implement and may allow for more degrees of freedom. It is worth noting that there is still a long way to go until stable, robust EMG control is achieved for home-use lower limb prostheses.

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Free Paper Session
Prosthetics: Upper Limb 1

1.6.2.a

Intramuscular Electrodes And Regenerative Peripheral Nerve Interfaces Can Reduce Cognitive Effort During Prosthetic Grip Selection

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BACKGROUND
Regenerative Peripheral Nerve Interfaces (RPNIs) amplify efferent nerve signals via suturing muscle grafts to severed nerve endings. Intramuscular electrodes in residual muscles and RPNIs can record electromyography (EMG) signals with specificity and consistent placement. As such, this approach may address the limitations of current surface pattern recognition systems for multi-grasp myoelectric hand control, including need for frequent recalibration [1] and high cognitive costs [2].

AIM
This study compares the cognitive effort associated with prosthetic grip selection between controllers using intramuscular electrodes with RPNIs and surface electromyography.

METHOD
The participant was a 54-year old female with a right transradial amputation. Bipolar electrodes were surgically implanted into three RPNIs and five residual innervated muscles. Eight gelled surface electrodes were placed over residual forearm muscles. The participant completed a virtual grasp matching task [3] using signals from either intramuscular (RPNI) or surface electrodes. For each set of signals, linear discriminant analysis classifiers were trained to decode Rest and up to four distinct grasps. The task was repeated simultaneously with the Controlled Oral Word Association Test (COWAT). For each condition, we quantified task accuracy and completion time.

RESULTS
The participant completed the task with higher accuracy for the RPNI (94.9%) compared to surface (76.8%) condition. Successful trials were completed in similar times with the two control modes. Adding a cognitive task had a negative impact on both task accuracy and completion time for most conditions. For three grasps, task accuracy decreased with the cognitive task by 8.7% and 4.3% for the surface and RPNI conditions, respectively. Across all grasps, time to complete successful trials increased with the cognitive task for the surface and RPNI conditions by 0.52 and 0.49 s.

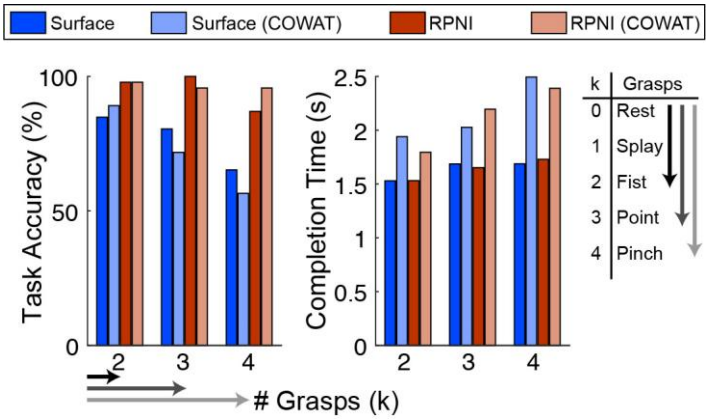

Figure 1. (Left) Task accuracy (n=46) and (right) completion time of successful trials between surface and RPNI conditions (k=2, 3, 4). Reduced opacity denotes trials with simultaneous dual task (COWAT).

DISCUSSION AND CONCLUSION
The impact of concurrent cognitive tasks on grip selection accuracy and completion time was greater in the surface than the RPNI condition. This suggests that use of RPNIs with intramuscular electrodes can effectively reduce cognitive effort and offer a more intuitive means for multi-grasp control. Future work should investigate the cognitive effort associated with using RPNIs to control a physical prosthetic hand, involving postural changes and object interaction.

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1.6.2.b
Functional Outcomes from Finger Prostheses for Digit Amputation

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BACKGROUND
Digit amputations are extremely common. Persons with digit amputations suffer both a functional and a psychological loss. Loss of finger length inhibits or fully prevents many hand grasp patterns required for daily activities. Active mechanical finger prostheses which restore certain grasp functions are now more widely available; however, the ability of standard outcome measures to show change in function with finger prostheses have not been clearly documented.

AIM
The purpose of this case series was to explore the responsiveness of outcome measures for three individuals with multiple digit amputations fit with active mechanical finger prostheses.

METHOD
Three clients with multiple digit amputations seen at a tertiary rehabilitation hospital were fit with trial versions of the NP Prosthetics™ metacarpal phalangeal (MCP) or proximal interphalangeal (PIP) Driver prostheses (Table 1). Outcome measures collected with and without the prostheses included the Activities Measure for Upper Limb Amputees (AM-ULA), Box and Blocks test (BBT), and grip strength. In addition, the number of achievable grasp patterns and pictures of hand grasp patterns were obtained, as well as functional goals.

RESULTS
The AMULA score improved (2 cases > minimal detectable change). The BB score worsened. Grip strength did not change for 1 case due lack of dynamometer contact*, but increased for cases 2, 3. All users increased the number of achievable grip patterns and attained functional grasping goals.

	Case 1		***Case 2***		***Case 3***	
NP prosthesis driver	D2-4 MCP		D2,3 MCP		D1,2 MCP; D4 PIP	
Prosthesis	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
AMULA (/72)	53	60	55	58	45	51
BBT	53	43	40	33	28	25
Grip strength-setting 2	10.7	10.7*	48.7	50.3	19	21.3
-setting 4	NA	NA	41.3	46	NA	
Tip pinch (lbs/sq")	NA	9	4	12	9	NA
lateral pinch (lbs/sq")	19	24	16	22	14	20
tripod	NA	NA	NA	16	16	7
Number of grasps (/16)	7	16	8	16	4	16

DISCUSSION AND CONCLUSION
Outcome measures for individuals with digit amputations should focus on documenting overall functional grasp patterns rather than speed based or grip strength parameters. The AMULA did show responsiveness to the intervention, possibly because it takes into account movement quality and skilfulness. Using these measures may improve our understanding of the improvements in function with finger prostheses. Objective evidence may also increase success rates to secure funding for partial hand prostheses, thus improving patients' access and quality of life.

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1.6.2.c

Comparing Dexterity, Activity Performance, Disability, and Quality of Life, of Body Powered and Myoelectric Upper Limb Prosthesis Users

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BACKGROUND
Although the advantages and disadvantages of upper limb prosthesis control strategies have been described historically, a recent systematic review comparing body-powered (BP) and myoelectric (MYO) prostheses found no clear superiority by device type and called for additional research to compare them.

AIM
To compare dexterity, activity performance, disability, health-related quality of life (HRQoL) and community integration for persons with upper limb amputation (ULA), by amputation level, prosthesis type and laterality.

METHOD
Data was collected during in-person visits in a multi-site, cross-sectional, observation study. Data were collected on functional performance and self-report measure measures. Participant characteristics and prosthesis type for unilateral and bilateral amputation and by amputation level were described. Outcomes were compared by amputation level and laterality using Kruskal-Wallis and Wilcoxon Mann-Whitney non-parametric tests due to small sample sizes. Control for multiple comparisons was performed. Wilcoxon Mann-Whitney tests were used to compare dexterity scores for those with unilateral transradial (TR) and those with bilateral amputation who had dominant side TR amputation.

RESULTS
Participants were 127 prosthesis users; 97% male, mean age 57 years, 59% BP prostheses users. All measures of dexterity differed ($p<0.05$) by amputation level and by laterality. All measures of activity differed by amputation level with the best scores in TR amputation groups. Comparisons of BP users with TR amputation found that dexterity was better for those with bilateral compared to unilateral amputation. Activity measures differed significantly by prosthesis type. In the TR group, BP users completed the fewest items on the Brief Activity Measure for Amputees (BAM-ULA) ($p<0.01$). No differences in activity scores by prosthesis type were observed for the TH group.

DISCUSSION AND CONCLUSION
We detected few differences in dexterity, activity performance, disability, HRQoL or community integration by prosthesis type. Further research is needed to explore whether there are differences by specific terminal device brands or functionality. An interesting finding was that dexterity was better for those with bilateral amputation compared to those with unilateral amputation, suggesting increased prosthesis engagement results in better prosthetic function

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ACKNOWLEDGEMENTS: This research was funded by the Orthotics and Prosthetics Outcomes Research Program Prosthetics Outcomes Research Award under Award # W81XWH-16-0794 and A9264-S Dept of VA RR&D Service.

1.6.2.d

Perspectives from Health Professionals, Users and Their Relatives on Upper Limb Prosthetic Requirements: A Qualitative Study

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BACKGROUND

The hand function is one of the most difficult to replicate due to its dexterity. For this reason, upper limb prostheses have a high rejection rate (39% to 53%) [1] caused by intrinsic prosthesis characteristics, its functionality, and the lack of training [1-4]. Prosthetic adherence may improve if health professionals, users, and their relatives' perspectives are included in the definition of the design requirements as it would take into account the main stakeholders' needs.

AIM

To define the desired characteristics of upper limb prostheses from the perspectives of health professionals, users, and their relatives to improve prosthetic adherence.

METHOD

Telephone or online surveys were conducted with upper limb amputees, their relatives and health professionals involved in the provision of services in upper limb amputation. Amputees were included if they were myoelectric, mechanical, or cosmetic prosthetics users or non-prosthetic users. Health professionals included: hand and orthopaedic surgeons, physicians, physical therapists, and orthotists/prosthetists. Each participant was given a list of prosthetic characteristics in which they had to rate the importance on a Likert scale (5 very important, 1 not important).

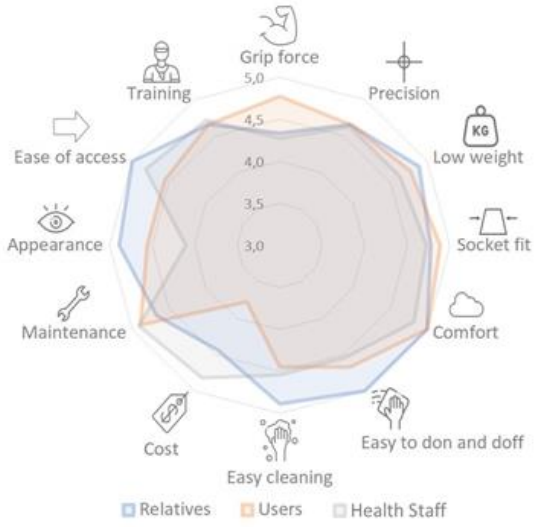

Figure 1. Importance of prosthetic characteristics for the three surveyed groups (11 health professionals, 11 upper limb amputees, and 10 relatives)

RESULTS

The amputees' ages ranged from 31 to 40 years old; 60% of them were men. The most prevalent cause of amputation was occupational accidents.
There was a lack of knowledge for users and their relatives regarding prosthetic functions and acquisition process.

The participants agreed that comfort was a critic prosthetic characteristic. The cost of the prosthesis was more critical for health professionals as they must follow health regulations for the provision. "Easy cleaning" and "easy don and doff" were relevant for relatives since amputees usually need help with these activities. Appearance was more important for relatives than users and health professionals. Health professionals agreed that understanding the preferences of the users and their relatives is vital for prosthesis prescription.

DISCUSSION AND CONCLUSION

Comfort was the most important characteristic for the participants. Socket fit was a main characteristic for users. The cost of the prosthesis was more important for health professionals. Surprisingly, appearance was more important for relatives than users. Emphasizing the needs of end users probably facilitates prosthetic fitting according to published literature [1-3, 5, 6]. Since the importance of characteristics is different for end users, their relatives and health professionals we propose to include these preferences into prostheses design and research.

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1.6.2.e
Grip Testing of 3D Printed Prosthetic Hand Featuring Adaptive Grasp

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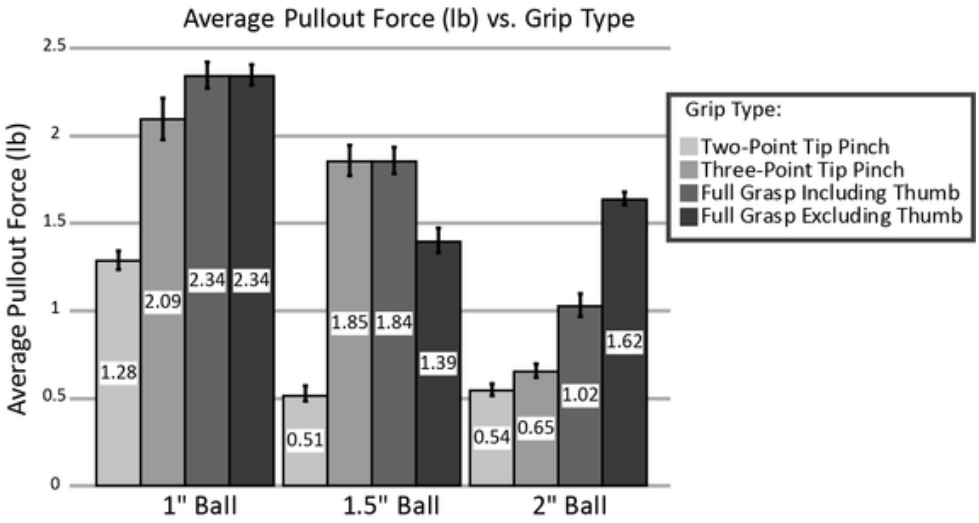
BACKGROUND
Pull-out tests were performed with a 3D printed hand containing adaptive grasp, which allows the hand to conform around objects of various sizes. Similar pull-outs have been performed by groups such as Dechev et al. [1] and Belter et al. [2]. Adaptive grasp is seen as advantageous because it helps the hand grasp different sized objects more securely. Each finger moves semi-independently which allows for more contact area on the held object.

AIM
To determine how adaptability of fingers (i.e. adaptive grasp) in a 3D printed hand affects the grip strength and performance of the hand for different grasps.

METHOD
The hand was tested using a pulley system with weights and three different sizes of 3D printed balls to measure the grip strength. Four different grips were tested: Two-point tip pinch, Three-point tip pinch, Full Grasp including thumb, Full Grasp excluding thumb. The Two-point and Three-point tip pinches contain the 3D-printed ball between the thumb and the index finger and between the thumb and the index finger and middle finger, respectively. The Full Grasp completely encloses the ball within the fingers with and without the thumb. A closing force of 10lbs was applied to the hand and experimental pullout force was recorded for each grip.

RESULTS
The results presented in Figure 1 shows an average pullout force for three ball sizes (1.0”, 1.5”, and 2.0”) and different pinch grips. Three tests were performed for each ball size and grip, and an average of the results was found. The highest pullout force occurred when the hand performed the Full Grasp grips due to the adaptive grasp allowing the fingers to conform to the shape of the ball. The smaller sizes of balls also led to a higher pullout force for the various grip types. The two finger pinch grip (i.e. index finger and thumb) was consistently the lowest pullout force.



DISCUSSION AND CONCLUSION
Adaptive grasp allows for better grip performance than a standard two-point tip pinch. The results show consistently higher pullout forces for three-point tip pinch grips and full grasp grips, corresponding to a more secure grip. This is due to the fingers being able to conform around different sized objects to maintain a better grip. By having both the thumb and fingers involved with the grip, the ball was enclosed, preventing it from slipping out of the hand prematurely.

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Free Paper Session
Training and Therapy

1.6.3.a

Aerobic Training in the Initial Prosthetic Training Phase for Patients with Lower Limb Loss due to Peripheral Vascular Disease

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BACKGROUND
Walking with lower limb prosthesis increases metabolic cost of walking and causes notable strain to the person's vascular system. However, aerobic capacity in patients amputated due to peripheral vascular disease (PVD) is 30% lower than in healthy population of the same age (1, 2). In order to decrease vascular complications during prosthetic and later phases of rehabilitation it is necessary to improve the ability of their cardiovascular system.

AIM
The aim of our study was to find out whereas with an individually prescribed aerobic training on hand-wheel we can improve the ability of cardiovascular system in patients with LLL due to PVD.

METHOD
Ten patients after trans-tibial (TT) and ten after trans-femoral (TF) amputation admitted for initial prosthetic training were included into study and randomised into 2 groups. All have regular rehabilitation program which includes also exercise on hand-wheel. Patients in exercise group practice four weeks 3 times per week on hand-wheel at 70 – 80 percent of heart rate reserve determined by exercise stress test, while the patients in the control group exercise based on their subjective feelings. Before and after we did exercise stress test in both groups and measure maximum oxygen consumption (VO_{2peak}), 6-minute walk tests. Study was approved by Ethic Committee.

RESULTS
Seventeen men and three women on average 65 years old were included in the study. In both patients groups (after TT and after TF amputation) the improvements in VO_{2peak} was significantly and clinically importantly higher in the experimental group (TT control 2.4, experimental 6.4ml/kg/min; TF control 3.1, experimental 7.3ml/kg/min), whereas distance on 6 minute walk test was significantly and clinically importantly longer only in patients after TT amputation (control 177m, experimental 262m). During exercise we did not have any complications or side effects.

DISCUSSION AND CONCLUSION
Individually prescribed aerobic training improve cardiovascular capacity in healthy and people with some chronic diseases (3). Based on the results of our study aerobic training without any complications improves cardiovascular ability in patients with LLL due to PVD. This may improve their ability to walk with prosthesis and functional outcome.

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1.6.3.b

Self-Management for Amputee Rehabilitation Using Technology with Support of Peers: A User-Centred Web-Based Program for Lower Limb Loss

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BACKGROUND
More than 7,300 Canadians experience lower limb loss each year. Comprehensive rehabilitation and education after limb loss are required to address physical and psychological complications. In person, self-management programs provide education and support and increase patients' coping skills to better manage amputation-related complications. However, in-person rehabilitation programs are costly and available mainly in urban regions.

AIM
To develop an online self-management program for individuals with lower limb loss, called Self-Management for Amputee Rehabilitation using Technology (SMART), and how this program will be tested in an early randomized controlled trial (RCT).

METHOD
The 6-step Intervention Mapping Framework was used which includes following steps: 1) needs assessment using interviews to explore patients and clinicians' perspectives; 2) creating matrices of the performance objectives to translate needs to content; 3) selecting theory-based intervention methods to apply the performance objectives in SMART; 4) developing and pretesting the prototype version of SMART using think-aloud cognitive processing approach; 5) planning for SMART adoption, implementation, and sustainability; and 6) generating an evaluation plan to assess effectiveness on relevant health-outcomes, fidelity and acceptability.

RESULTS
Clinicians (n=31) and patients (n=26) were recruited to understand the rehabilitation educational content and health issue of amputation. Goal setting, understanding the amputation, care, life at home, prosthetic care and activities were identified as performance objectives. The instructions on how to perform a behaviour, demonstration of the behaviour, verbal persuasion, self-monitoring and action planning were used to apply determinants in SMART. The usability of prototype version was tested on patients (n=9) to find technical issues, comprehensibility of information, pictures, and videos clarity. In collaboration with stakeholders, SMART was designed and consisted the instruction manual, weekly contacts of peer, email, or telephone reminders to revisit the program. An evaluation plan was developed that will involve an RCT to assess the 6-week effectiveness of SMART on patient-relevant outcomes, while documenting implementation factors (n=82).

DISCUSSION AND CONCLUSION
SMART is an online self-management program which provides information regards to post amputation complications. SMART is delivered with support of peers and has the potential to address the gap and improve amputation outcomes regardless of geographical boundaries.

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1.6.3.c

The Effect of Telehealth Interventions on Mobility for Individuals with Lower Limb Loss: A Systematic Review and Meta-Analysis

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BACKGROUND
Mobility is a crucial construct in healthy aging after lower limb loss (LLL). Telehealth technologies, e.g., smartphones, are novel approaches for health programs' delivery regardless of geographical boundaries.

AIM
Following a systematic review and meta-analysis, we synthesized the randomized controlled trials on the effect of telehealth interventions compared to usual care and written material on mobility in adults with LLL aged over 50 years.

METHOD
Seven databases were searched including, MEDLINE, PubMed, Embase, CINAHL, Cochrane, PsycINFO, and SPORTDiscus. The last search was updated on January28, 2021 to identify relevant publications. Two reviewers independently screened the records at level 1 and 2. First, they screened titles and abstracts, level 1, then full texts, level 2. The reasons for exclusion were recorded at level 2. Two reviewers assessed risk of bias using Cochrane Risk of Bias tool. We conducted a narrative synthesis of evidence. We conducted a meta-analysis using the standardized mean difference (SMD) and MD. Two reviewers used Grading Recommendations Assessment, Development and Evaluation (GRADE) rating approach for practice recommendations.

RESULTS
Six studies were included. Telephone was the most common delivery mode (n=3). Tablet-based app was used in two studies and video-based training in one study. Telehealth interventions showed a positive effect on mobility compared to a control condition (6 studies: SMD=0.43 [95% CI=0.04, 0.81], P=0.03). However, the certainty of evidence was very low.

DISCUSSION AND CONCLUSION
Our review highlighted a gap in literature for the effect of telehealth interventions for individuals with LLL. Despite the small positive change in mobility after telehealth interventions, the very-low certainty evidence precludes us to make a firm conclusion for healthcare professionals. Remote delivery of health programs using telehealth technologies can potentially improve mobility for individuals with LLL regardless of geographical boundaries, which can promote equity in terms of access to educational resources.

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ACKNOWLEDGEMENTS: We acknowledge Vancouver Coastal Health Research Institute to support this study and AGE-WELL: Canada's Technology Network to support Esfandiari.

1.6.3.d

The Effects of Spinal Stabilization Exercises on Functional Capacity of Individuals with Transtibial Amputation

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BACKGROUND

Lower limb amputation causes rapid changes in the musculoskeletal system. With the effect of these changes, the functional exercise capacity and exercise energy requirement for ambulation with prosthesis changes compared to normal ambulation. Although methods such as reducing the segmental load of the prosthesis and choosing different prosthetic components are emphasized for the optimization of the energy expenditure, within our knowledge, the effect of exercise types has not been investigated.

AIM

The aim of this study was to investigate the effect of spinal stabilization exercises on the stabilization strength of deep spinal muscles, exercise capacity, energy expenditure, fatigue and perceived mobility level with the prosthesis in individuals with unilateral transtibial amputation.

METHOD

Eighteen participants were divided into two groups as “Group1” and “Group2” randomly. Classical physiotherapy program was applied to Group1, and spinal stabilization exercise training was applied to Group2 together with classical physiotherapy program. At the beginning and end of exercise training; the stabilization strength of the deep spinal muscles (mmHg) was evaluated with "Pressure Biofeedback Unit". Maximal oxygen consumption ($MaxVO_2$) (mL/kg/min) and maximal energy expenditure (MaxEE) (kcal/h) were evaluated during “6 Minute Stepper Test” (6DST). Fatigue assessment was done before and after 6DST with the "Modified Borg Scale". The effect of the prosthesis on the perceived mobility level evaluated with "Prosthesis Evaluation Questionnaire-Mobility"(PEQ-M).

RESULTS

In the intergroup comparisons, the change in the stabilization strength of deep spinal muscles, MaxEE and $MaxVO_2$ values were found to be statistically significant in both groups ($p<0.05$). In the comparison between groups, the changes in the stabilization strength of deep spinal muscles, $MaxVO_2$, MaxEE and PEQ-M were found to be significant in favour of the group in which spinal stabilization exercises were applied ($p<0.05$) (Table 1).

	Change in Group 1 (X±SD)	**Change in Group 2 (X±SD)**	**p**
Stabilization strength of deep spinal muscles(mmHg)	0.22±0.15	3.16±1.12	**0.000***
$MaxVO_2$ (mL/kg/min)	0.09±0.09	3±3.22	**0.000***
MaxEE (kcal/h)	6.44±7.38	74.78±123.3	**0.009***
Fatigue	-0.78±0.75	-0.17±1.27	0.131
6DST (number of steps)	13.78±8.74	42.44±51.78	0.062
PEQ-M	-0.09±4.23	16.42±8.34	**0.000***

Table 1. Comparison of exercise-induced changes between groups

DISCUSSION AND CONCLUSION

As a result of this study, it was determined that although both the classical physiotherapy program and spinal stabilization exercises had a positive effect on the parameters evaluated, spinal stabilization training should be included in the amputee rehabilitation program. It has been showed that adding spinal stabilization exercises to the rehabilitation program increase the exercise capacity, the amount of energy available without fatigue, and the perceived mobility level which are among the options to increase functional capacity.

1.6.3.e

Use of Myoelectric Upper Limb Orthosis Combined with Motor Learning-Based Therapy in People with Chronic Stroke and Traumatic Brain Injury

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BACKGROUND

Upper limb deficits are common after stroke and traumatic brain injury (TBI) with recovery often limited even after therapy. Adjuvant treatments that enhance motor learning-based (MLB) therapy may improve outcomes. MLB therapy consists of part and full task practice, while the MyoPro is a myoelectrically-controlled elbow-wrist-hand orthosis that harnesses the user's electromyography (EMG) signal to assist motion of the impaired hand and elbow.

AIM

The purpose of this pilot clinical trial was to assess the feasibility of delivering combination MLB therapy and MyoPro in a mixed cohort of persons with chronic stroke and TBI.

METHOD

Subjects with chronic stroke and TBI were recruited. After custom fabrication/fitting of MyoPro, subjects participated in an In-clinic phase (MLB therapy with MyoPro; 1.5 hours twice weekly; 9 weeks) followed by a Home-use phase (home exercise program with/without MyoPro; 9 weeks). Outcome measures (Table 1) administered without MyoPro at baseline and end of both phases. Movement cycles logged by MyoPro motors. Outcomes assessed univariately for association with diagnostic group (continuous variables using Welch two-sample t-tests; categorical variables using Fisher's exact tests). Longitudinal linear mixed effects models included fixed effects for time, adjusted for baseline status and diagnostic group, and random effects for subjects (two-sided significance = 0.05).

RESULTS

As shown in the Table 1, 13 subjects (7 stroke, 8 females, 50.6±19.9 years, 99.3±116.8 months post-injury) participated in the study. At baseline, TBI subjects were significantly younger than stroke subjects with higher baseline CAHAI scores. Despite these differences, diagnostic group and baseline status did not influence the model (except for MAS and Satisfaction) but assessment time did. For the entire cohort, significant changes were observed for all measures at both time points, with the exception of CHART (significant change in participation did not occur until end of Home phase). Device repetitions during the Home phase were significantly greater for the TBI cohort at the elbow. No adverse events occurred.

Table 1 Subject characteristics and results by diagnostic group and phase. Significant results are shown in bold.

		Total (n=13)	TBI (n=6)	Stroke (n=7)	p
Gender	f	8 (61.5)	3 (50.0)	5 (71.4)	0.59
	m	5 (38.5)	3 (50.0)	2 (28.6)	
Age		50.6 (19.9)	33.3 (11.5)	65.4 (11.4)	<0.0001
Months post Injury		99.3 (116.8)	163.7 (147.7)	44.1 (37.8)	0.06
Baseline (Mean (SE))					
FM		29.23 (9.95)	35.00 (11.31)	24.29 (5.44)	0.05
MAS*		8.58 (3.02)	8.67 (3.43)	8.50 (2.90)	0.926
CAHAI		29.61 (16.17)	40.83 (17.49)	20.00 (5.86)	0.012
OPUS_SAT		51.00 (19.32)	41.67 (16.13)	62.20 (17.89)	0.076
CHART		338.86 (98.52)	358.82 (109.74)	321.76 (92.94)	0.52
Home Phase					
Total elbow cycles		5401.62 (6283.41)	9563.40 (7586.92)	2428.93 (3043.79)	0.046
Total hand cycles		11141.29 (9974.43)	16618.50 (11542.16)	7229.00 (7122.20)	0.11

n=13	Baseline to end of in-clinic phase (Mean(SE))	Baseline to end of home phase (Mean(SE))
FM	7.32 (1.10) (p<0.0001)	7.55 (1.10) (p<0.0001)
MAS*	-2.54 (0.31) (p<0.0001)	-2.31 (0.31 (p<0.0001)
CAHAI	7.46 (1.34) (p<0.0001)	8.85 (1.34) (p<0.0001)
OPUS_SAT	25.00 (4.87) (p=0.0004)	26.73 (4.87) (p=0.0003)
CHART	14.22 (13.60) (p=0.3162)	34.91 (13.60) (p=0.0247)

*Sum of 9 arm muscles, lower score = lower tone. For all other measures, higher scores = better outcome.

DISCUSSION AND CONCLUSION

It was feasible and safe to deliver the combination therapy. Combined therapy of 27 hours in clinic resulted in improvement of impairment (FM) that was close to that reported with 150 hours of in-person MLB therapy alone [1]. While most outcomes improved during the in-clinic phase and were maintained during the home-use phase, participation as assessed by CHART improved through both phases.

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Tuesday, 2 November

Symposium
Prosthetics: Upper Limb

2.2.1
Best Practice and Advances in Paediatric Upper Limb Prosthetics

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Abstract
Paediatric upper limb prosthetics (including both congenital and acquired limb loss) is an area where prosthetic technology is advancing. Health systems differ in how these advances are being incorporated into the mainstream. There is limited evidence and data around cost benefit analysis making it difficult to adopt these newer technologies and yet there is a need to improve the quality of care and outcomes for children and into adulthood. It is timely to look at specific research priorities and key areas for development.

This symposium will present a summary of findings and collation of professional opinion in best practice from a collaboration between ISPO-UK upper limb special interest group, prosthetic centre in the UK and a further one in Sydney, Australia. Key priorities of research will be presented and discussed as well as challenges within the respective health systems. Presenters will cover advances in surgical approaches, occupational therapy and training, to prosthetic provision and the experience of the incorporation of newer technologies.

Statement of the learning objectives
Identify key areas of best practice in children's limb deficiency and prosthetic rehabilitation
Identify key research priorities for further research
Reflect on the experience of two different health systems incorporating newer technology

Free Paper Session
Orthotics: Lower Limb – Foot Orthoses

2.2.2.a
Effects of Insoles on Plantar Contact of Floating Toes

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BACKGROUND
Toes play important role in static, dynamic balance, and stability of walking [1, 2]. “Floating toe” may occur in normal adults and children, which decreases toe-grip strength and forward transfer ability and increase the mechanical stress on the knee and lower back during gait [3]. However, no attempts have been made to investigate the effect of insoles on “floating toes” in the healthy population.

AIM
An attempt was made to clarify the effect of three months usage of a custom insole on the toe plantar contact during gait.

METHOD
Ninety-two male and female (51.8 ± 19.7 years,160.6 ± 8.8 cm, 56.5 ± 11.6 kg) participated in the study by wearing their own custom-made insole in their daily life for three months. Foot morphology and plantar pressure distribution were collected before and after the intervention using a 3D foot scanner (DreamGP Inc. Osaka, Japan) in sitting and standing postures and a plantar pressure mat while standing (RSscan International, Belgium). Floating toes are classified as follows: I:1 to 3 foot digits contact, II:4 to 6 foot digits contact and III:7 and more foot digits contact. To identify the level of comfort and satisfaction of the insole, a survey was conducted to evaluate the insoles.

RESULTS
There was a 4% reduction of the category I population and a 5 % increase of the category III population who have 7 and more foot fingers contacting the ground. Regarding the perception of insoles, the custom insoles received good satisfaction for the forefoot (77%; n=71), arch support pad (78%; n=72) and heel pad (87%; n=80) regions from the participants. The survey about the comfort of insoles showed that 58.7% (n=54) of the participants reported improvement of pain around some body part after the three months usage of the insoles.

DISCUSSION AND CONCLUSION
Floating toes have been associated with foot deformities and malalignments, thereby possibly increasing the mechanical stress on the knee [3]. That might cause pain or other instability of some body part. Use of custom-made insoles for 3 months improved the plantar foot contact aspects especially for the increased number of foot digits contacting the ground. This apparent change might straighten the foot alignment thereby improving the posture of participants during their daily living activities such as standing and walking.

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2.2.2.b

The Effect of Heel Lifting and Gastrocnemius Stretching Exercise on Range of Motion and Pain in Boys with Calcaneal Apophysitis

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BACKGROUND

Calcaneal apophysitis is aseptic necrosis of the growth plate in the posterior part of the calcaneus and is the most common cause of heel pain in children (1). In conservative treatment, reducing the load on the area, activity modification, heel lifts, stretching and strengthening exercises for the triceps surae muscle, cold applications and when necessary, anti-inflammatory and analgesic drugs are frequently used (2). Heel lift is one of the best-known treatments for pain relief (3).

AIM

The aim of our study was to examine the effects of heel lift and gastrocnemius stretching exercise on normal range of motion and pain in boys with calcaneal apophysitis.

METHOD

Thirteen boys aged 8-11 years, who were diagnosed by the physician and had a positive bilateral heel compression test, participated in the study. The foot postures were evaluated with the Foot Posture Index. Pain intensity was evaluated with Numeric Rating Scale (NRS) and pain thresholds with digital algometer, ankle dynamic dorsiflexion with lunge test and statically with universal goniometer before and after the treatment. The children were asked to use 6 mm Ethyl Vinyl Acetate (Shore-A35) heel lift with proper sports shoes for 1 month and to perform bilateral gastrocnemius stretching exercises with 3 sets of 10 repetitions per day. The research was approved by the ethics committee.

RESULTS

The mean age of the children was 9.4 ± 0.6 years, and the body mass index was calculated as 17.2 ± 4.9 kg/m². While 45.5% of the children had overpronation, 13.6% of them had normal foot posture. After the treatment, it was found that the pain threshold and dynamic dorsiflexion angle improved in both extremities compared to before ($p<0.05$). When the clinical effect of this improvement was examined, it was found that the improvement in left pain threshold and right dynamic dorsiflexion angle had a great effect ($r \geq 0.5$) (Table 1).

Table 1. Comparison of pre-treatment and post-treatment evaluation parameter

Variables	Pre-treatment	Post-treatment	p*	r
	$\bar{x}$±SS			
Pain Rest (cm)	2.3 ± 1.3	1.6 ± 1.1	0.057	
Pain Activity (cm)	5.8 ± 1.5	4.3 ± 1.0	**0.004**	0.57
Pain Threshold Right, kg/cm²	2.2 ± 0.5	2.7 ± 0.3	**0.004**	0.58
Pain Threshold Left, kg/cm²	2.2 ± 0.4	2.7 ± 0.3	**0.001**	0.63
Static Dorsiflexion ROM Right, °	14.1 ± 3.5	16.3 ± 1.6	**0.018**	0.47
Static Dorsiflexion ROM Left, °	15.6 ± 2.6	16.0 ± 2.4	0.217	
Dynamic dorsiflexion ROM Right, cm	6.0 ± 1.6	7.5 ± 2.1	**0.002**	0.61
Dynamic Dorsiflexion ROM Left, cm	5.8 ± 16	7.1 ± 2.0	**0.003**	0.58

*: Wilcoxon Signed Rank Test. r: Effect Size, ROM: Range of Motion

DISCUSSION AND CONCLUSION

Heel lift and stretching exercises are effective in reducing pain during rest and activity and increasing dorsiflexion ROM in boys with calcaneal apophysitis. In this context, orthosis and stretching exercises should be considered as a component of conservative treatment in children with calcaneal apophysitis. In order to generalize our results, randomized controlled studies with larger samples are required.

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2.2.2.c
Effect of 3D Printed Insoles for People with Flatfeet: a Systematic Review

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BACKGROUND
Flatfoot describes feet with visually dropped medial longitudinal arches often associated with rearfoot eversion and forefoot abduction. These people often complain of foot pain and fatigue after walking and occasionally experience associated ankle and knee pain. Foot orthoses (insoles) are an effective intervention in rehabilitation to control excessive foot pronation and decrease pain for people with flexible flatfeet. Among different types of insoles, 3D printing technology has become a popular technique to create insoles in recent years.

AIM
The purpose of this systematic review was to evaluate custom-made 3D printed insoles for people with flatfeet.

METHOD
This review considered studies without any language limitation, which (1) compared outcomes with and without 3D printed insoles; (2) compared 3D printed insole with a conventional insole; and (3) included individuals with both flexible and rigid flatfoot. This review was conducted based on the PRISMA guideline. The PubMed, Embase, ISI web of knowledge databases, ProQuest, Scopus, and Cochrane based on the population intervention comparison outcome (PICO) method, were searched from inception until December 2020. Outcomes of interest were included pain, foot function, plantar pressure, and gait parameters (kinematics, kinetics, and electromyography). The quality assessment of included studies was performed through the Downs and Black checklist. A narrative analysis was performed since meta-analysis could not be conducted.

RESULTS
In total, 12 studies of 227 subjects with flexible flatfoot were chosen for the final evaluation. Outcomes of interest were considered but not limited to pain, foot function, plantar pressure, and gait parameters. Although the relevant papers' evidence was generally weak, using insoles with 3D printing technology may positively affect pain (comfort score) and foot function, with no significant change in vertical loading rate during walking or running. There were discrepancies among the papers for plantar pressures, the centre of pressure trajectory, and 3D ankle joint kinematics and kinetics of gait while wearing these insoles. Dose-response effects of posting in 3D printed insoles may have beneficial effects on lower limb gait biomechanics of flatfeet. There was insufficient evidence to conclude the comparison of 3D printed insoles with other types of insoles.

DISCUSSION AND CONCLUSION
Although the evidence from the relevant papers was generally weak, insoles using 3D printing technology may positively affect comfort score and foot function. Dose-response effects of 3D printed insoles may have beneficial effects on gait biomechanical outcomes of flatfeet. There was insufficient evidence to conclude the comparison of this insole with other types of traditional insoles. To further provide evidence of the efficacy of 3D printed insoles for flatfeet, several research areas need to be addressed in future studies.

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2.2.2.d
Placebo Insoles - Just a Sham? A Methodological Review

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BACKGROUND
A validated sham insole is critical to conducting a double-blind, randomised, placebo-controlled trial: the gold-standard trial design for assessing efficacy. To facilitate blinding the sham should convince a participant that it could be the treatment insole and have negligible, or at least known, biomechanical effects. The insole evidence base is regularly critiqued for poor trial design often without control groups,[1,2] but there has been minimal consensus of design through validation of sham insoles for use in clinical trials.

AIM
This systematic methodological review aimed to define current usage of sham insoles in clinical trials, for all conditions and participants, focusing on:

- How are sham insoles constructed?
- How are the biomechanical effects assessed?
- What measures are undertaken to ensure blinding?

METHOD
A comprehensive literature search was conducted in June 2020 MEDLINE, Embase, CINAHL, and CENTRAL. Synonyms for 'insoles' and 'sham' were used in combination with relevant truncations, wildcards and Boolean operators to identify relevant articles. Studies of all conditions and ages of participants were included to capture a complete summary of sham insoles across all orthotics research. The literature search strategy produced 270 records, after review and exclusion 24 clinical trials were included in the review. The search was repeated in January 2021 and no new studies were included.

RESULTS
There is no widely accepted or validated sham construction. No two studies described the same sham insole.
How are sham insoles constructed?
19% of sham insoles were described sufficiently to be replicated. 55% of sham insoles were constructed from ethylene-vinyl acetate (EVA); 67% were completely flat without arch shaping.
How are the biomechanical effects assessed?
Biomechanical properties of sham insoles were rarely investigated and poorly reported. The most common method for assessment was in-shoe plantar pressures. All sham insoles which were assessed significantly altered the plantar pressures compared to the shoe-only condition.
What measures are undertaken to ensure blinding?
Participants were not informed about the sham group, cast in line with standard manufacture, or sham and treatment insoles were made to look similar to maintain blinding. To blind investigators, participants were asked to remove and hide shoes.

DISCUSSION AND CONCLUSION
The poor reporting on construction, and limited understanding of biomechanical effects, of sham insoles makes it difficult to interpret individual study results or synthesise data between studies. It is also not clear how successful blinding techniques are, potentially introducing bias to results. Validation of a sham insole, credible to at least participants with minimal biomechanical influence, is critical to improving the insole evidence base. Standardised reporting guidelines of insole construction would also be valuable to improve reporting and interpretation.

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2.2.2.e
Custom Insoles Evaluation in Safety Footwear in an Industrial Environment

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BACKGROUND
Long working hours in an industrial environment with safety shoes can increase the development of musculoskeletal complaints. In a previous study on occupational footwear, Johnson [1] stated that prolonged standing and walking on hard floors might be the main causes of foot problems while wearing safety shoes, shoes that do not fit correctly, and a habitual wearing of the wrong shoes. These safety shoes when not well stabled can cause fatigue and falling during working.

AIM
The aim of this study was to evaluate the effects of safety shoes on gait and plantar pressure distributions and centre of pressure (COP) on an industrial flooring with customized insoles.

METHOD
Seventy-two workers (52 males, 20 females, age: 48.2 ± 10.5 years, height: 165 ± 3.9 cm, weight: 66.9 ± 11.5 kg) participated in the study. Foot data were collected using a 3D foot scanner (Dream GP Inc., Japan) to design custom insoles. Two safety shoes were used for evaluation. One shoe with the prefabricated insole (footwear A) and the other with a 3D customized insole (footwear B). Plantar pressure data were collected in 9 month period using prefabricated and 3D custom insoles with Footscan pressure plate (Rsscan International, Belgium). Peak pressure and COP displacement during each condition were determined for analysis. Mean values were compared using paired t-tests ($p < 0.05$).

RESULTS
The peak plantar pressure evaluated in the different foot zones showed significant values when wearing footwear A and footwear B. From heel to toe, the footwear A showed higher pressures (Fig.1). The footwear B fitted with 3D foot morphology customized insoles reduced considerably the peak plantar pressure. Also, a significant decrease of peak pressure was observed in footwear B with prefabricated nine months later. The footwear A shows higher values in medial direction compared to the footwear B with custom insoles during the propulsion phase of the gait. The effects of the custom insole in the footwear B had tendency to stabilize the body laterally during propulsion phase of the gait (Fig.2).

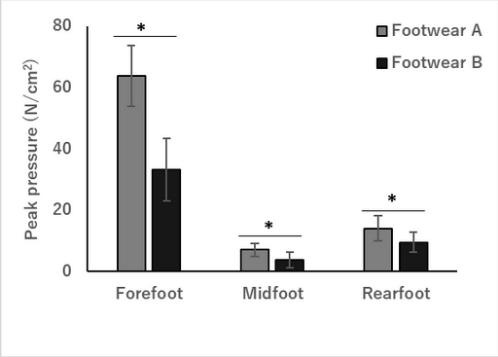

Fig. 1: Comparison of peak pressure of the foot regions between the two footwears, *p < 0.001

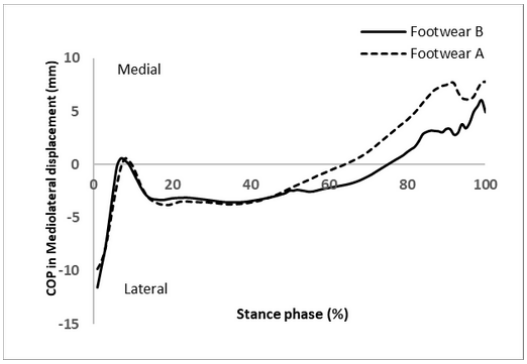

Fig.2: COP coordinate in the ML direction during stance phase

DISCUSSION AND CONCLUSION
It can be suggested that the heel cup of the custom insole better accommodates the calcaneus during initial contact of the gait cycle. Our study analysed the foot in 3 regions anatomically: forefoot (phalanges and metatarsals), midfoot and rearfoot. The custom insoles evaluated in this industrial environment had a great influence on the plantar pressure distribution. Using a 3D foot morphology customized insole will improve gait comfort and stability thus preventing fatigue, injuries and falling in an industrial environment.

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Free Paper Session
Phantom Limb Pain

2.2.3.a
New Evidence in the Theories Behind Phantom Limb Pain: A Systematic Review of the Literature, 2015-2020

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BACKGROUND
At the time of this review, there is no consistently reliable treatment option for phantom limb pain in those with limb-loss. Critical stages in pain signal transfers and processing are analysed; how the body alters internally following amputation may provide a key insight into the underlying cause of phantom limb pain. Recent advantages in neuroimaging techniques and a plethora of insufficient treatment options preceding 2015 highlight further gaps in the knowledge of this complex condition.

AIM
To outline the most recent developments in understanding the phantom limb pain phenomenon and offer a new insight into how this new evidence intertwines with older theories.

METHOD
Four electronic research databases were searched in October of 2020 using a combination of keywords and Boolean operators; non-English and data pertaining to animal testing were excluded, as were studies focusing on non-painful phantom sensations. Papers were appraised using the SIGN grading system and papers scoring a quality grade poorer than 2+ were excluded.

RESULTS
Twenty-five articles were included within the review. The papers used a mixture of collection methods such as questionnaire and fMRI to obtain data from a total of 737 subjects. A number of overlapping themes were evident including the maladaptive plasticity and neuromatrix models, the pain memory theory and psychological factors, sensitised nervous systems, and phantom limb ownership.

DISCUSSION AND CONCLUSION
Phantom limb ownership plays a larger part in the pain experience than previously considered; phantom pain severity is affected by multiple factors thus several patient-specific treatments must be explored. Phantom limb pain strongly correlates with the ability to move and control the phantom limb; multiple systemic malfunctions or changes following amputation are thought to be at fault. Ownership of the limb is essential for successful rehabilitation; further evidence is required to confirm additional theories.

2.2.3.b
Patients' Experiences from a Novel Treatment of Phantom Limb Pain

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BACKGROUND
Phantom limb pain (PLP) is a deteriorating condition that can greatly diminish quality of life. A novel treatment has been developed to relieve the PLP. The Phantom Motor Execution (PME) program uses augmented reality to treat PLP. The PME treatment will bring to life areas of the brain that have been inactive, which may have effects on their PLP, phantom sensations, self-agency, daily activities or sleep.

AIM
The aim was to describe patients' experiences from undergoing phantom motor execution treatment.

METHOD
A descriptive, qualitative design was used. Semi-structured interviews were used to collect data. Categories entailed participants experiences of PLP, sensations of PLP, effects of PLP on daily life, and experiences with content of PME treatment. The framework approach was chosen for analysis. Reporting of the study followed COREQ checklist to ensure quality. Ethical approval was obtained. Each participant provided written informed consent. Interviews were held 1 month after PME treatment with independent researcher.

Patients with amputation who have undergone PME treatment in Sweden (n=9) and the Netherlands (n=12) were recruited. In total 21 patients were included: Mean age 56.7 years, 16 males, 5 upper and 16 lower limb amputations.

RESULTS
Preliminary data show that most participants experienced different degrees of relief of their PLP due to getting command over their phantom movements and because they learned to relax their phantom limb. A few participants did not experience any change in their PLP. Some participants acknowledged that they were allowed to have a phantom and had learned to perceive it as a positive feeling. Some were able to use exercises learned during treatment in their home situation without having the PME system, others were unable to do so without the visual stimulation of the augmented reality. Due to the therapy, the PLP was experienced as less intrusive in daily life. For some the treatment was energy consuming, due to the mental effort that was required to follow the full treatment. Final results will be presented during conference.

DISCUSSION AND CONCLUSION
The PME treatment seems to be a promising addition to existing treatments for PLP. Most patients experienced relieve because they learned to get control over their phantom and to regard their PL sensations as positive. However, not all patients experienced a decrease in PLP, so further research is needed to improve the PME treatment in order to be able to help these patients as well.

2.2.3.c

Interplay Between Innovation and Intersubjectivity. How Therapists Providing Phantom Motor Execution Therapy Describe and Explain Change

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BACKGROUND
The effects of Phantom Motor Execution (PME) on pain outcomes was evaluated within an international randomised control trial [1]. While this quantitative investigation focused on changes in pre-specified health outcomes, pain is not experienced in isolation and may be influenced by interpersonal processes [2]. The presence of the other may impact on the experience of pain and an observer can be impacted by the pain in others [2]. How this complex social scene may influence PME outcomes is unexplored.

AIM
This study employed qualitative methodologies to explore subjective perspectives on the PME and elicit therapists` view on how affect, motivation, behaviour, and interpersonal context may have impacted outcomes within the context of a unique and novel rehabilitative process.

METHOD
A Framework Method was used to explore therapists` (n=11) subjective experiences of PME treatment, meanings attached to it, and the mediating role of intra- and interpersonal factors; including therapeutic alliance. Purposive sampling strategy was employed and semi-structured, online-based interviews were used to collect data from therapists working with the PME system. An interview guide was informed by a framework of contextual factors modulating therapeutic outcomes. Both inductive and deductive analytical approaches were employed. After developing a working analytical framework, the analysis was completed with the use of NVivo software. Credibility of findings was ensured by involving a multidisciplinary team. Standards for Reporting Qualitative Research were followed to ensure rigor.

RESULTS
In the therapists` views, the PME therapeutic effects occurred within a complex system of interactions, involving the key actors: therapist, patient, and PME device. This 3-way interaction, an overarching construct tying four themes together, formed the context for change and an interplay between innovation and intersubjectivity. The perceived therapeutic effects (theme 1) extended beyond those hypothesised for the PME therapy and highlighted the need for diverse conceptualisations of success and surprising effects. Participants recognised mediating role of the key actors and context (theme 2). Therapeutic relationship was described as a journey (theme 3) and perceived as both a cause and a consequence of therapeutic effects. The PME context was an opportunity for collaboration, communication, and bonding. Potentials and future directions for PME (theme 4) were highlighted, with customisation of the system solutions and their enabling aspects being viewed as the strongest points.

DISCUSSION AND CONCLUSION
This qualitative investigation pointed to intra- and interpersonal factors that should be considered in clinical implementation of novel rehabilitative tools and their role for therapeutic effects. Further examination of the interplay between these complex factors and a novel rehabilitative tool may also inform the design of new rehabilitative strategies. The need to account for context and intersubjectivity is highlighted and directions for future studies are suggested.

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Symposium
Prosthetics: Lower Limb

2.3.1
Prosthetics for Low-and-Middle-Income Countries (LMICs): Challenges and Opportunities

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Abstract
The World Health Organisation estimates that 650 million people worldwide are disabled. Of those people, 80% currently live in Low- and Middle-Income countries (LMICs) that are often at various stages of economic development depending on active conflict or post conflict state. Fewer than 3% of persons with disabilities in LMICs have access to required rehabilitation services. Without access to the rehabilitation they require, those with disability may become entrenched in a cycle of poverty. There is a need for functional prosthetics which are affordable, robust, reliable and fit-for-purpose in resource constrained settings of LMICs. To address some of those LMICs developmental challenges, an integrated multidisciplinary partnership was convened between Indian and UK Engineers, Prosthetists, Healthcare professionals and experts from prosthesis manufactures, and public health NGOs. This consortium held exclusive networking meetings both in India and UK, supported by the UK Academy of Medical Sciences under Global Challenges Research Fund Networking Grants. The team also engaging with interdisciplinary research for developing Upcycled Plastic Prosthetic supported by the UK's Royal Academy of Engineering Frontiers follow-on grant.

This symposium will be delivering the findings from those research projects involved with LMICs as well as the UK stakeholders to inform the current thinking on the LMICs prosthetics requirements. These includes the unmet need of the LMICs amputees, capacity building to build skills across career stages with partners in LMICs during the preliminary trials of Upcycled Plastic Prosthetic, as well as integrating hands-off casting for prosthetic socket fabrication in LMICs protocol.

Statement of the learning objectives
- The unmet need of the LMICs amputees
- Capacity building case studies to build skills across career stages with LMICs partners
- Development of Upcycled Plastic Prostheses
- User-engagement experiences of hand-off casting in LMICs setting

Advanced Instructional Course
Orthotics: Spinal

2.3.2
Innovations in the Design of Hard Rigid Braces for Adolescent Idiopathic Scoliosis Treatment

Guerrino Rosellini[1,2,3,4,5], Stefano Negrini[6,7,8], Fabrizio Tessadri[9]

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Abstract
Bracing has been accused of “no evidence” for years, slowing the progression of research. For these reasons, the international Society on Scoliosis Orthopedic and Rehabilitation Treatments (SOSORT) has produced a series of Consensuses and Guidelines to drive clinics and research. A well designed RCT published in 2014 was stopped for ethical reasons because the high efficacy of bracing did not allow more recruiting to the “no-treatment” control group. As a result, research is growing again. Among the innovations in this century are hard rigid braces, developed to avoid casting. Currently they include two devices: the Sforzesco (Italy) and the ART (France) braces. They differ mainly in symmetricity amount and, consequently, in biomechanical action. Published results show their efficacy also in curves above the surgical threshold. Proper timing in prescription, correct design and building provides a possibility to avoid surgery and improve trunk aesthetics. Biomechanical principles applied to braces cannot ignore a design tailored to the patient and a controlled fabrication process. One of the most significant problems in brace management is the conflict between the rigid part of the brace and the pelvis in the three spatial planes. The lateral parts of the iliac bones stop the frontal corrections. The sagittal compression also changes the biomechanics of the pelvis. An innovative idea aims to reduce those problems by introducing soft material pelvis containments and a gradual back closure system. It enables us to obtain an increasing progression of the correction forces without the strains, which usually spoil our work.

Statement of the learning objectives
This instructional course aims to give attendees information about the latest guidelines, brace classifications, state of the art of hard rigid braces and biomechanical concepts, and technical innovations in design and fabrication.

Free Paper Session
Psychosocial Issues / Quality of Life

2.3.3.a

How do Activity, Prosthetic Fit, Comfort and Community Participation Correlate in Lower Limb Prosthesis Users? A Cambodian Pilot Study

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BACKGROUND
After amputation, many people become inactive, feel lonely and lose their independence, so measures of effective prosthetic provision and rehabilitation should include physical activity and community participation [1]. Understanding the factors associated with low physical activity and community participation in Cambodia could contribute to defining key interventions which can support prosthesis-users so they can live a more active and socially inclusive lifestyle.

AIM
To characterise physical activity and community participation using actimetry and questionnaires in a Cambodian cohort of established lower-limb amputees.

METHOD
Factors affecting physical activity and community participation were assessed using an array of measures. At study commencement and 3-6 months later, 20 established prosthesis-users (11 transtibial and 9 transfemoral) completed a questionnaire and a weekly timetable to determine demographics, activity, community participation, societal perceptions, and prosthesis satisfaction, fit and comfort. An accelerometer was embedded in the prosthesis to collect 10 weeks of activity data.

RESULTS
Participants were active, averaging 4650 steps/day, and wore their prosthesis for most waking hours, averaging 14 hours/day. Figure 1 shows Spearman correlations between variables. Steps/day correlated moderately with self-reported activity levels (p = 0.41), hours of wear (p = 0.66) and years since amputation (p = 0.50). Community participation correlated moderately well with hours of wear (p = 0.59), and level of amputation (p = 0.56). Reported satisfaction, fit and comfort correlated strongly with years since current socket fit (p = 0.84, 0.99 and 0.83 respectively), but did not correlate with activity or community participation (-0.13 ≤ p ≤ 0.19).

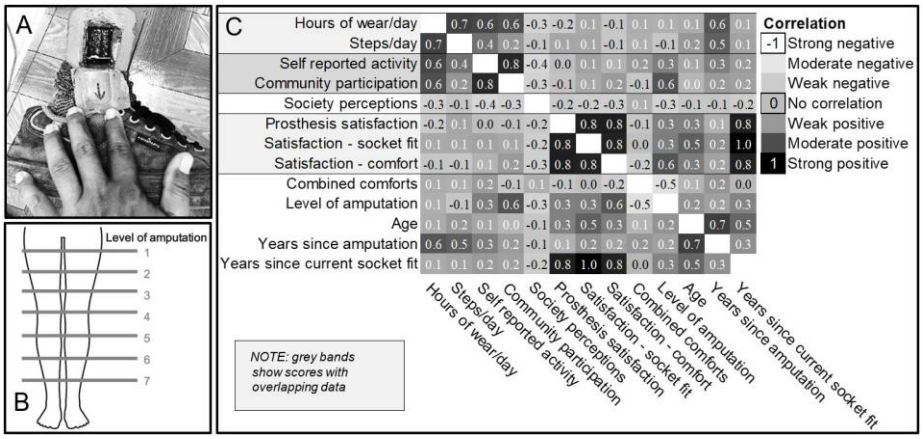

Figure 1. A. Accelerometer embedded in the prosthesis, B. Level of amputation, C. Spearman correlation matrix of variables

DISCUSSION AND CONCLUSION
Accelerometers can provide objective information to assess the effectiveness of prosthetic interventions, alongside surveys and outcome measures. The small sample size means these correlations should be used with caution, but they indicate variables worthy of further study to understand barriers to community engagement and physical activity for prosthesis-users in Cambodia.

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ACKNOWLEDGEMENTS: Ethics: NECHR(311), ERGO(45577). Funding: EPSRC(EP/R014213/1) and RAEng(RF/130).

2.3.3.b
Everyday Life in Uganda for People with Upper Limb Absence

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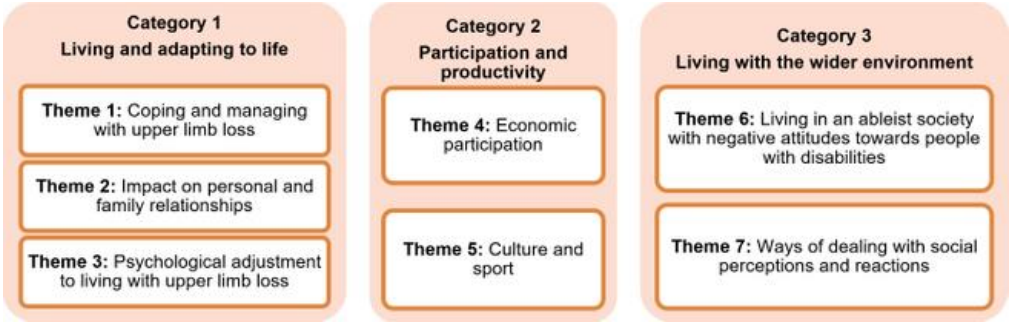
BACKGROUND
Approximately two million people live with limb loss in Eastern Sub-Saharan Africa [1-4]. High incidence of upper limb amputations is due to trauma and 25% of amputations in Africa relate to the upper limb [1]. In contrast to individuals with upper limb amputations in high income countries, very few papers have been published on the experiences of individuals with upper limb absence in African countries or other low resource settings.

AIM: To explore the lived experiences of people with upper limb absence (PWULA) living in Uganda.

METHOD
Scoping and exploratory work was carried out to underpin this research. This involved informal scoping interviews within a 'Public, Patient Involvement' framework with clinicians, technical staff, and people with upper limb absence. Face-to-face semi-structured interviews were conducted by local team members after getting appropriate training from experienced researchers, which helped ensure the exploration of deep cultural diversity. A convenience sampling approach was used to recruit 17 PWULA who were registered with an orthopaedic clinic in Kampala, contacted by telephone. These included people with unilateral and bilateral limb loss. The interviews were audio recorded, transcribed, and thematically analysed.

RESULTS
Participants' experiences were categorised according to how they adapt to upper limb absence or amputation, how they perceived their disability affected their relationships with others and their roles in society, and how they are treated due to their disability, as illustrated in Figure 1. Only two participants had experience of using a prosthesis. Participants felt discriminated and labelled negatively across various aspects of daily life affecting their psychological wellbeing, employment, community participation and social (intimate, friendship, family) relationships. Nevertheless, some participants reported receiving positive support from friends, family members and through their religious communities and beliefs or relying on their self-esteem. None of the participants reported having access to psychological and occupational services.



DISCUSSION AND CONCLUSION
The challenges experienced by PWULA in Uganda are comparable to concerns posed by the UN Committee on the Rights of People with Disabilities in 2016 [5]. We recommend that future research and interventions consider the social and cultural issues presented in this paper. These findings illustrate the importance of increasing support networks for individuals with disabilities, involving them the provision of psychosocial and occupational services and for dismantling discrimination and stereotypes.

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ACKNOWLEDGEMENTS: All participants, Mulago Orthorpaedics Workshop, Henry Gizamba, Yosiah Muhindo, James Kirabira, Mark Kalibbala, Carolyn Gribble, UK-Global-Challenges-Research Fund/EPSRC/NIHR(EP/R013985/1).

2.3.3.c
Influence of Health Beliefs on Self-Management in Persons with Lower Limb Loss

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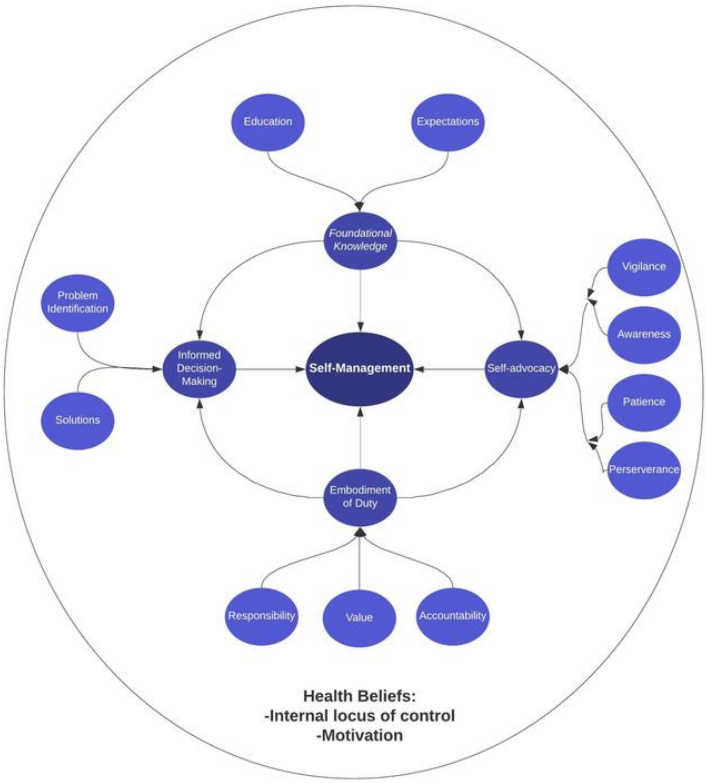
BACKGROUND
A person with lower limb loss (PwLLL) must be proficient in self-managing (SM) their residual limb, prosthesis, and the socket-interface to prevent secondary complications of the integumentary and musculoskeletal systems. This process of SM can be an arduous journey for some, while for others presents little challenge. Gaining perspective from the primary stakeholders (PwLLL, prosthetists, and physical therapists) about the SM experience provides insight into the barriers, facilitators, and challenges a PwLLL faces as well as help guide clinical practice.

AIM
The aim of this study was to explore the experience of self-managing from the perspective of persons with limb loss, prosthetists, and physical therapists.

METHOD
This study utilized a qualitative design within a phenomenological framework. To be eligible to participate in the study, one of the following criteria needed to be met: prosthesis user who is independent in self-managing their residual limb and prosthesis, certified prosthetist (either ABC or BOC), or a licensed physical therapist with experience working with PwLLL. A sample size of 20-25 participants was projected for the study, with an approximate 1:1 ratio of PwLLL to clinicians. Participants were interviewed using semi-structured interviews that were audio recorded, transcribed, coded, and then analysed for themes. The constant comparison method, commonly used with phenomenological analysis, was employed to determine codes and resultant themes.

RESULTS
Twenty-three participants were interviewed (PwLLL=10, prosthetists=7, physical therapists=6) and data saturation was achieved. Four prominent themes were developed from the transcripts: 1) embodying the duty of self-management, 2) being a vigilant self-advocate, 3) setting goals collaboratively, and 4) making informed decisions. Each of the four themes were influenced by the health-beliefs of the PwLLL, specifically motivation and presence of an internal locus of control. The figure demonstrates the theoretical framework of self-management for a PwLLL. Individual narrations representing each theme will be presented.



DISCUSSION AND CONCLUSION
Having dominion over all aspects of self-management is the influence of health beliefs, specifically the role of motivation and an internal locus of control, which both serve as important elements of the self-management process. Health beliefs are recognized as a key component of successful self-management for persons with chronic and long-term conditions. Clinicians can support the PwLLL in self-managing through patient, collaborative goal setting, and reinforcement of an internal locus of control. Specific strategies will be reviewed.

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2.3.3.d

The Impact of the COVID-19 Restrictions on Physical Activity and Quality of Life in Adults with Lower Limb Amputation

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BACKGROUND
As a response to the COVID-19 pandemic, the Norwegian authorities introduced restrictions to society that promoted social distancing and limited travelling. People with lower limb amputation (LLA), who generally experience limitations in community mobility, might experience the impact on their daily life different from nondisabled people. It is hypothesized that the restrictions negatively affect health-related quality of life, and will decrease prosthetic wear time and ambulatory activity in persons with LLA.

AIM
To investigate the impact of the COVID-19 restrictions on ambulatory activity and quality of life in people with LLA.

METHOD
Twenty persons (four females) with a transtibial (n=11), transfemoral (n=6), knee-disarticulation (n=2), and bilateral transtibial (n=1) amputation participated in the study. Mean ± SD age and time since amputation was 55.5 ± 11.9 and 22.3 ± 20.1 years, respectively. Initial data were collected prior to the pandemic, and follow-up 8-12 months later. Quantitative measures included ambulatory activity measured over seven days (StepWatch: prosthetic wear time, steps per day, minutes of low-intensity (<15 steps min^{-1}) and high-intensity (> 40 steps min^{-1}) ambulation), and health-related quality of life (EQ-5D-5L). Qualitative data were collected via semi-structured interviews to achieve a deeper understanding of individual experiences with COVID-19 restrictions.

RESULTS
Prosthetic wear time decreased significantly (-61 ± 90 minutes per day, $p < .01$). Contrary to the hypotheses, non-significant increases were found for steps per day (440 ± 1481) and EQ-5D-5L index score (.02 ± .10). Likewise, high-intensity ambulation increased (5 ± 14 minutes per day), while low-intensity ambulation decreased (-2 ± 16 minutes per day), but changes were non-significant. Qualitative analysis identified three themes important for coping with restrictions: (1) mindset, (2) being a prosthetic user in times of social distancing, and (3) personal situation.

DISCUSSION AND CONCLUSION
Increased time spent at home might have resulted in decreased prosthetic wear time, while more free time might have facilitated participants being physically active outside the home. A positive mindset, motivation, and good prosthetic functioning may be important factors for maintaining ambulatory activity and high quality of life in people with LLA. Yet, the inability for physical contact with peers was experienced as a limiting factor in providing information and social support, particularly for newly amputated individuals.

Symposium
Prosthetics: Lower Limb

2.4.1
LEAD (Lower Extremity Amputation Dataset): Outcome of a Global Consensus

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Abstract
ISPO International, with the support of USAID, ATScale and UNOPS has undertaken an international consensus to develop the LEAD (Lower Extremity Amputation Dataset) for people undergoing lower-limb amputation and prosthetic rehabilitation.

Currently, there is a large amount of variability in data domains collected about people with lower limb absence, including in the areas of research, national registries and in smaller data sets at the regional and centre level. To facilitate more uniformity to allow combination of datasets, more robust comparisons and a better standard of reporting to allow clear interpretations, the LEAD has been developed. Other recommendations include domains useful for development of a registry.

This symposium will:

- Describe a scoping review of data sets related to lower limb absence and rehabilitation and related assistive products.
- Describe results from semi-structured interviews about limb loss and prosthetic rehabilitation registries and data sets.
- Detail a global consensus of multidisciplinary clinicians, users, policy makers and researchers who have established a set of recommended data elements, based on their real-world experience and knowledge of outcome measure utility and applicability.
- Describe the LEAD and its data dictionary
- Share the recommendations for data management, data collection, compliance with privacy legislation, stakeholders, funding, registry design and other matters related to development of a patient registry.
- Provide examples of registry development and lessons learned from two patient registries, the SwedeAMP and the Limb Loss and Preservation Registry.

Statement of the learning objectives
The symposium will introduce the LEAD and present the consensus process that developed it. Other relevant issues concerning registries and data sets will be discussed.

Free Paper Session
Orthotics: Spinal

2.4.2.a

Introducing Pelvis Semi-Rigid Material does not change Short-Term Very-Rigid Sforzesco Brace Results. A Matched Case-Control Study in AIS

Stefano Negrini[1,2], Fabrizio Tessadri[3], Francesco Negrini[2], Marta Tavernaro[4], Fabio Zaina[4], Andrea Zonta[4], Sabrina Donzelli[4]

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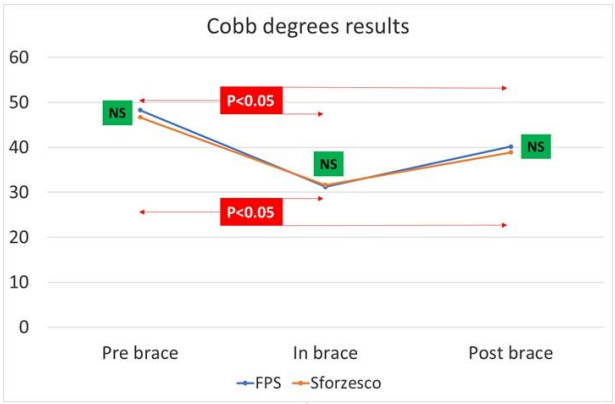
BACKGROUND
We recently introduced pelvis semi-rigid material (ethylene vinyl acetate) to improve sagittal balance, brace comfort, and adaptability of VRB, but this could also negatively impact the corrective forces on the trunk.

AIM
Does the “Free Pelvis” (FP) innovation affect results in adolescents with idiopathic scoliosis (AIS) treated with very-rigid (high-density polyethylene) Sforzesco brace (VRB)?

METHOD
Study Design. Matched Case-Control Study. **Participants**. *Inclusion criteria*: AIS, age 10-16, VRB prescribed 23 hours/day, x-rays available, primary curve 36-65°, Angle of Trunk Rotation 7-23°. *Cases*: VRB with FP (FPB). *Controls*: classical VRB matched for Risser (range 0/4), menarche age (10/15), weight (33.5/83), height (140/180), BMI (13.5/29), aesthetics (TRACE 4/12), plumbline distances (S1: -60/35; C7+L3: -10/115), referred brace use (22/24). **Statistics**. *Linear regression* outcome: short term variations - start to first out-of-brace x-ray. *Logistic regression* outcome: improved vs worsened. *Explanatory variable*: brace type.

RESULTS
We included 777 VRB (36% of the initial 4431) and 25 FPB (26%), age 13±1, 47±7° and 48±10° Cobb, 11% and 16% males, respectively. **Baseline characteristics** differed only for bracing before first consultation (+26% VRB), reported brace use (+12’/day FP) and recorded compliance (+1% FPB). The sensitivity analysis provided the same results. **°Cobb corrections**. *Short-term (5±2 months)* -7.8±0.2 for VRB and -8.1±1.3 for FPB (p= 0.83); *in-brace* -15.2±7.7 and -17.4±6.5, respectively (p=0.21). Type of brace influenced °Cobb neither short-term (coeff. -0.30, CI95% -2.4;1.8 R^2=0.0001), nor in-brace (2.2, CI95% -0.64;5.1 R^2=0.002). Brace type didn’t affect odds of improvement (OR 0.60, CI95% 0.3;1.4 adj R^2=0.002).



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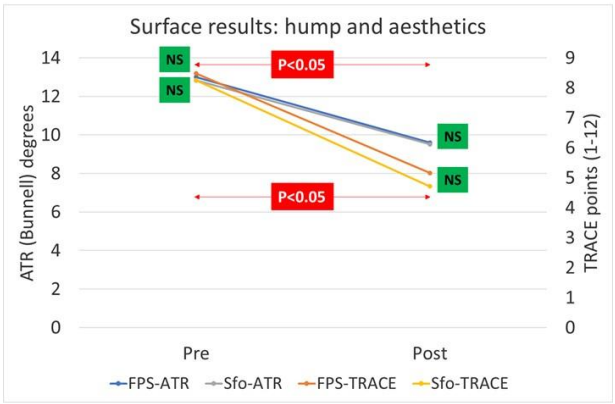

B

Figure 1: The Free-Pelvis has radiographic (A) and clinical (B) results similar to classical very-rigid bracing.

DISCUSSION AND CONCLUSION
FP's introduction for comfort, adaptability, and sagittal balance does not change in-brace and short-term results of classical Sforzesco VRB. Semi-rigid pelvis material (“Free Pelvis”), introduced to improve comfort, adaptability, and sagittal balance, does not change in-brace and short-term efficacy of classical Sforzesco very-rigid brace for high-degree AIS.

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2.4.2.b

Reducing the Pelvis Constriction Changes the Sagittal Plane. A Retrospective Case-Control Study of Free Pelvis vs Classical Very-Rigid Sforzesco Braces

Stefano Negrini[1,2], Fabrizio Tessadri[3], Francesco Negrini[2], Marta Tavernaro[4], Fabio Zaina[4], Andrea Zonta[4], Sabrina Donzelli[4]

[1]University "La Statale", Milan, Italy. [2]IRCCS Istituto Ortopedico Galeazzi, Milan, Italy. [3]Orthotecnica, Trento, Italy. [4]ISICO (Italian Scientific Spine Institute), Milan, Italy

BACKGROUND

The sagittal plane preservation is one of the main aims of modern bracing. The Sforzesco brace, ancestor of very-rigid (VRB) group, has a push-up action to decrease brace's adverse sagittal effects. Recently, semi-rigid material for the pelvis (FPB) has been inserted in the Sforzesco VRB to allow patients spontaneously achieving their in-brace sagittal balance. We aimed to compare the sagittal radiographic results of FPB vs VRB.

AIM

Does the "Free Pelvis" (FP) innovation change the sagittal plane results of very-rigid bracing (VRB) for adolescents with idiopathic scoliosis (AIS)?

METHOD

Study Design: case-control study. We extracted from our prospective database all FPB and VRB at the first consultation. Inclusion criteria: AIS, age 10-16, VRB prescribed 20 hours/day, sagittal x-rays available at the first and either at the second consultation or in-brace (at 1-month) . We checked in-brace and out-of-brace thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI) and tilt (PT), sacral slope (SS), and lumbosacral angle (LSA). We also checked TK/LL, PT/SS and LSA/LL ratios and PI-LL difference.

RESULTS

We included 451 (10.2% of 4431) VRB and 37 (38.5%) FPB, age 13±2, °Cobb 42±11° vs 44±12°, and males 19% vs 14%, respectively. At baseline, we found no differences between groups for sex, age, Risser, menarche, menarche age, weight, height, BMI; ATR, aesthetics (TRACE index), plumbline distances; previous, prescribed, declared and performed bracing; starting, in-brace and post-brace frontal °Cobb. We found similar statistically and clinically significant TK reductions in both groups, and some statistically, but not clinically significant changes of lumbopelvic parameters. Changes prevailed at in-brace radiograph and in VRB.

DISCUSSION AND CONCLUSION

Free Pelvis innovation causes less in-brace lumbopelvic strain in VRB and slightly changes the short-term out-of-brace results. It is worthwhile exploring possible medium/long term changes. Semi-rigid material ("Free Pelvis") changes more the in-brace than the short-term out-of-brace sagittal balance of very-rigid Sforzesco brace. It is worth exploring—medium and long-term changes.

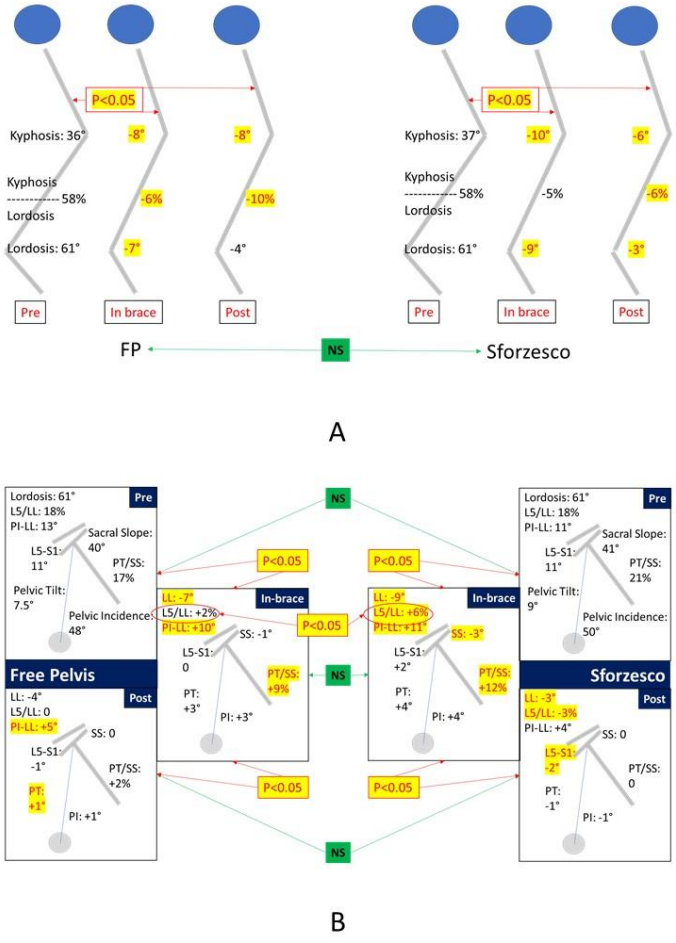

Figure 1: Sagittal balance in-brace and out-of-brace effects of the Free-Pelvis innovation in very-rigid bracing. White numbers for p<0.05 variations.

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2.4.2.c

Reducing Low Back Load and Metabolic Effort in Manual Materials Handling by Using a Passive Back-Support Exoskeleton

Thomas Schmalz[1], Emily Bywater[2], Christian Gaertner[3], Malte Bellmann[1], Michael Ernst[1]

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BACKGROUND
Low back pain caused by work-related musculoskeletal disorders (WMSD) is a major threat to workers in industry, especially in logistics. Newly developed exoskeletons are specifically designed to combat the development of WMSDs in the lower back by transferring load away from it. Objective scientific investigations are essential in evaluating the benefit that the user that can expect from these devices.

AIM
The purpose of the present study was to use an integrated approach to investigate the biomechanical and metabolic effects of a newly introduced exoskeleton designed to reduce low back loading during lifting tasks.

METHOD
Ten healthy subjects volunteered to participate (22.0 ± 2.3 y, 72.3 ± 11.5 kg, 181.6 ± 9 cm). The exoskeleton used was the Paexo Back exoskeleton (Otto Bock, Germany). To replicate a typical working situation, participants performed a repetitive lifting task (10kg box) with and without the exoskeleton (WE and WOE) for 5 minutes each.

Oxygen rate was measured using a spiroergometric system. Muscle activation was determined by using a wireless system with electromyographic sensors on participants' back, abdominal, and thigh muscles. Kinematic and kinetic data were recorded with an optoelectronic system and two force plates. Using the ANYBODY Modeling System, the orthogonal joint compression forces between L5/L4 and L5/S1 were calculated.

RESULTS
During the repetitive lifting task, the oxygen rate WE was significantly decreased by 10% compared to WOE ($p<0.05$). The participants used a similar motion pattern both for the WE and WOE cases without significant differences in their lower limb joint angle peak values. The integrated EMG for the back muscles shows a significant reduction in in the WE condition compared to the WOE condition by up to 14% ($p<0.05$). For the M.bic.fem., the integrated EMG shows a significant reduction WE by 15% ($p<0.05$).

The mean peak compression force in L5/S1 was reduced from 2857 ± 489 N in the WOE condition to 2264 ± 315 N in the WE condition ($p<0.01$). The same value in L4/L5 was reduced from 2900 ± 512 N in the WOE condition to 2293 ± 312 N in the WE condition ($p<0.01$).

DISCUSSION AND CONCLUSION
The results show that the tested exoskeleton augments the lifting task with an increased metabolic efficiency, a reduction in the back muscle activation required to conduct the task, and a reduction in low back loading. The results indicate that the use of the exoskeleton may prevent the development of work-related musculoskeletal disorders long-term.

2.4.2.d

A New Low-Cost Motion Capture System for Assisting Scoliosis Treatment

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BACKGROUND

Scoliosis is a three-dimensional spinal deformity and the radiographic result is a standard outcome measure. However, it only provides a two-dimensional result which is not enough to represent the whole deformity. Motion capture is an alternative method to measure the spinal outcome, however, the current system is expensive, not available in the clinic, and not specific for scoliosis application.

AIM

To develop a low-cost motion capture system for assisting scoliosis treatment and to investigate its accuracy.

METHOD

Raspberry pi with its camera was used for image processing and the main computer with developing software was used for calculating the camera calibration, camera position, and marker position. Raspberry pi communicated with the main computer wirelessly via a Wi-Fi router. In the current stage, three raspberry pi with its camera were initially used to capture the shape and investigate the system accuracy with a haft-circle surface object. Multiple white markers were attached on the surface and the program calculated marker positions. Finally, the root-mean-square error (RMSE) was calculated by using the values from the calculation in the program and known marker position.

RESULTS

For calculating marker position, these required at least one pair of cameras, and there will be 8 cameras in the whole system. However, the current stage started using three cameras to see the possibility of this development and it was enough to minimize the error by using 3 pair cameras (pair of cameras 1&2, 2&3, and 1&3). Moreover, the error was only focused on the marker position that could be seen by all pairs. Finally, the RMSE of X, Y, Z, and total error was 1.65mm, 1.44mm, 1.84mm, and 1.65mm respectively.

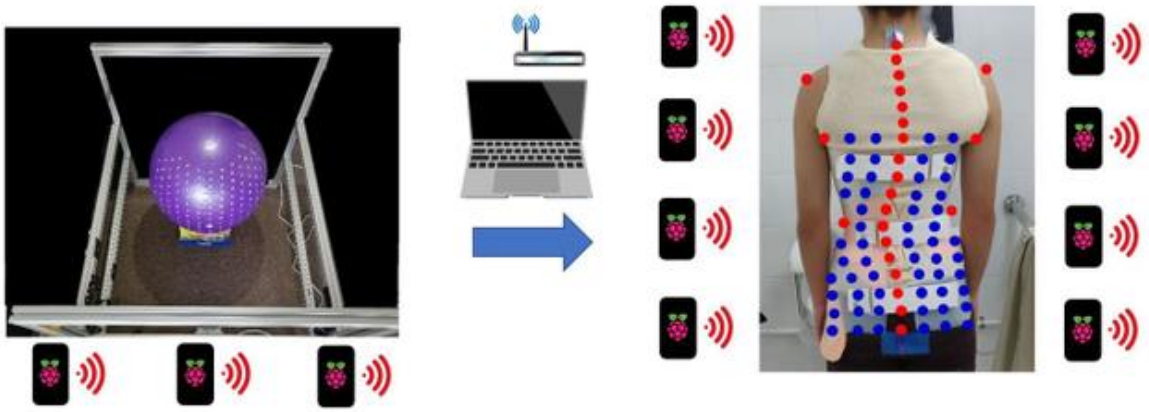

Figure 1: A new low-cost motion capture system, a). using 3 cameras to capture the surface and b) a conceptual idea by using 8 cameras to capture spinal parameters and shape

DISCUSSION AND CONCLUSION

Comparing the accuracy with a high-cost motion system, the error was less than 1mm in static and 2mm in dynamic conditions. The accuracy of a low-cost system was between ±5mm to ± 10mm and the suggested error was ±5mm. Therefore, our system showed an acceptable error (<5mm). Next step, the study will increase more cameras and use them to capture the spinal parameters to assist the scoliosis treatment.

ACKNOWLEDGEMENTS: Thanks, Faculty of Medicine Siriraj Hospital for scholarship. Thanks, University of Strathclyde and supervisor who always support my Ph.D. study.

2.4.2.e

An Alternative Conservative Approach for Managing Non-Specific Back Pain Amongst Larger Breasted Women?

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BACKGROUND
Due to current measurement, sizing and fitting approaches, poor bra fit is prevalent amongst larger breasted women. Poor bra fit is proposed to be a causal factor in the development of negative health outcomes including Non-Specific Back Pain (NSBP). Correct bra fitting has been suggested to provide significant symptomatic relief, although this hasn't yet been explored. As a self-management strategy, this conservative approach may provide women with independence, empowerment and active involvement in the long-term management of their pain.

AIM
To determine the potential effectiveness of an alternative approach for managing chronic NSBP amongst larger breasted women, this study aimed to explore immediate and short-term biomechanical, psychosocial and pain responses to changing breast support garment amongst symptomatic and asymptomatic participants.

METHOD
Asymptomatic participants (n=24) performed a static standing task, drop jumps and seated typing whilst kinematic data from the breasts and spine were recorded. Three breast support conditions were assessed: Usual, professionally fitted bra in the immediate term (PFB), and after four weeks wear (PFB_{28}). Bra fit assessments were included for both bras. Measures of conscious motor processing were made using the Movement Specific Reinvestment Scale. Symptomatic participants followed the same data collection protocol (n=24) however, five breast support conditions were included: Usual, PFB, PFB_{28}, and an Alternative Bra in the immediate term (AB) and after four weeks wear (AB_{28}) (Optifit, Saddleworth, UK). A combination of clinical pain questionnaires measured symptomatic change.

RESULTS
All asymptomatic participants failed the bra fit assessment in the Usual bra and 67% (n=16) in the PFB. Less bra fit issues were present in the PFB compared to the Usual bra, resulting in immediate biomechanical changes relating to breast support and spinal posture. These changes were not maintained over time (PFB_{28}). All symptomatic participants failed the bra fit assessment in the Usual bra, 87.5% (n=21) in the PFBs, and 4.2% (n=1) in the AB. The PFBs and ABs resulted in symptomatic relief post-intervention, with the ABs improving a greater number of clinical measures than the PFB. Biomechanically the AB maintained uplift over time through reduced Nipple-sternal-notch distance, whilst the PFB did not. Symptomatic relief may be associated to the resting position of the breast tissue on the anterior chest, rather than limiting dynamic breast movement or postural change.

DISCUSSION AND CONCLUSION
These findings suggest alternative measurement, sizing and fitting approaches, such as the AB within this study, may provide clinical benefit for patients when implemented as part of a multi-disciplinary conservative pain management approach for larger breasted women with NSBP. The potential wider benefits of improving bra fit for larger breasted women may include improved psychosocial wellbeing, empowerment of women to take control of a chronic condition and reducing barriers to physical activity, all of which warrant further exploration.

ACKNOWLEDGEMENTS
The Optifit Bra Company (UK) provided the alternative bras in-kind, internship funding and a University Investment Voucher funded staff time.

Free Paper Session
Prosthetics: Upper Limb 2

2.5.1.a
Identification of the Most Relevant Aspects that Determine Users' Value of Upper Limb Prosthesis: A Dutch National Survey

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BACKGROUND
Multi-grip myoelectric prostheses may have functional advantages, however, the value of these prostheses as experienced by its users seems often limited. We hypothesized that a high users' value requires a match between prosthetic aspects considered important by an individual and prosthetic features. Despite the increased focus on patient-centred healthcare, a patient-reported outcome measure (PROM) to assess the users' value of upper limb (UL) prostheses, of which contents are based on what is deemed important by patients, seems to be lacking.

AIM
To determine which aspects regarding prosthesis use were considered most important by adults with major unilateral UL absence for use in a novel digital PROM to assess the users' value of UL prostheses (UV-ULP).

METHOD
Based on 1) a meta-synthesis of qualitative literature, 2) a focus group among individuals with a UL absence, and 3) feedback from health care professionals, an overview of 79 aspects related to prosthesis use was created. These aspects were depicted in a software-based graphical diagram. Adults with major unilateral UL absence (N=358; mean age=55.4±16.5 years; 52.0% male/ 40.8% female/ 7.3% unknown) selected their top-10 most important aspects from this overview.

RESULTS
Most selected aspects were 'wearing comfort' (54.0%), 'grabbing, picking up and holding' (34.3%), 'weight' (31.4%), 'independence' (30.6%) and 'functionality' (30.0%). Women selected 'independence', 'household', 'life-like appearance', 'overuse complaints', and 'anonymity' more frequently compared to the overall population; men selected 'functionality' more. Persons with UL absence proximal from the elbow rated 'donning/doffing' more; persons with UL absence distal from the elbow rated 'household' and 'self-care' more. Mono-grip and multi-grip myoelectric prosthesis users selected more function-related aspects, while cosmetic/passive prosthesis users selected more comfort-related and appearance-related aspects. After evaluating the survey results, and combining related items, the following nine items were selected to include in the UV-ULP: 'wearing comfort', 'functionality', 'independence', 'work, hobby, and household', 'user-friendly', 'life-like appearance', 'phantom limb pain', 'overuse complaints' and 'reliability'.

DISCUSSION AND CONCLUSION
'Wearing comfort' was considered most important by persons with UL absence, which emphasizes the need to pay more attention to improvements of the comfort of UL prostheses. Subpopulations of prosthesis users showed different focus areas, which could be used in selecting or evaluating UL prostheses in clinical practice to deliver more personalized services. User values seem well presented in the new UV-ULP. This tool may be useful as an evaluation tool in clinical practice or future research.

ACKNOWLEDGEMENTS
The authors thank C.J. Blekkink, the rehabilitation centres, and prosthetic workshops for their support in sending surveys to the participants.

2.5.1.b

Passive Prosthetic Wrists: A Review of Commercially Available Designs and Their Suitability for Low-and-Middle-Income-Settings

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BACKGROUND

The wrist plays a key role in dexterity, however, the majority of upper limb prosthesis research focuses on terminal devices, not wrists [1]. Commercial wrist designs have also likely been developed for higher income markets. Such designs, particularly powered devices, may not be suitable for low-middle income settings (LMIS) in which activities of daily living, prosthetic services, and environmental demands differ markedly from high income settings.

AIM

To review the literature on passive prosthetic wrists, with a view to determining their suitability for LMIS.

METHOD

Passive prosthetic wrists are manually adjusted by the user with the contralateral limb or an environmental feature. To identify the set of passive prosthetic wrist designs, PubMed, Google Scholar, Medline and Science Direct were searched using relevant key words. In addition, websites, manuals and catalogues of manufacturers of passive wrist prostheses were searched. Identified devices were classified according to how adjustment is achieved. They were classified as sprung or un-sprung and offering freedom to lock the wrist at any point within the adjustment range, or in specific angles.

RESULTS

21 passive prosthetic wrists were identified. 14 of these offered a single DOF (11 offered pronation-supination and 3 flexion-extension), 7 offered 2 DOFs (5 flexion-extension and pronation-supination and 2 flexion-extension and radial-ulnar deviation.), only one offering 3 DOFs was found. There is limited consensus on how adjustment is achieved, and whether to offer freedom to lock the wrist at any point within the adjustment range, or in specific angles, which also varied widely, for example; Figure 1 shows the variations between the locking angles for wrists offering flexion-extension and whose locking angles were reported. User views on the DOF of most value to upper limb amputees also differ [2] [3]. Little information was found explaining the design rationales underpinning these designs. Finally, the few experimental studies identified came from the high-income countries.

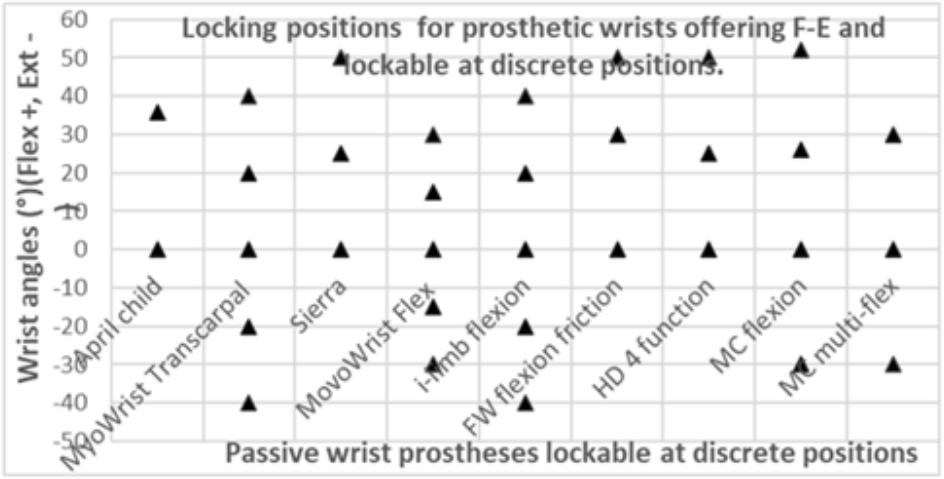

Figure 1. Flexion/extension locking positions for the passive prosthetic wrists whose locking positions in this DoF were reported.

DISCUSSION AND CONCLUSION

The results showed a lack of consensus on most aspects of passive prosthetic wrist design. Designs varied in terms of the degrees of freedom offered, the locking and adjustment mechanisms and ranges of motion. In order to develop prosthetic wrists which are suitable for people living with upper limb loss in LMIS, there is a need to better understand the design requirements.

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2.5.1.c
Upper Limb Amputation Rehabilitation Guidelines

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BACKGROUND
To date, no global data or guidelines for upper limb amputation rehabilitation exist. In this technological era, e-learning and virtual reality (VR) [1] are playing a key role in improving the rehabilitation experience. The project aims to develop and disseminate global standard guidelines for upper limb amputees' rehabilitation to ensure evidence-based practice combined with a patient centred journey. Through technology and VR, these guidelines will be utilised alongside standard rehabilitation processes to assist amputees in transitioning to the end prosthesis.

AIM
To develop rehabilitation guidelines for upper limb amputees and clinical personnel that can be disseminated globally.

METHOD
A systematic desk review identified key research gaps that require the development of global upper limb amputee rehabilitation guidelines. The desk review will be combined with discussions, reviews and feedback from a multidisciplinary and upper limb amputee working group (including service users, prosthetists and rehabilitation clinicians), helping to define key elements for inclusion in the overarching guidelines for upper limb amputee rehabilitation. Secondary to this, development of VR software will be designed with amputee input to further enhance the rehabilitation experience and provide alternative rehabilitation methods.

RESULTS
The desk review produced limited resources which explicitly stated rehabilitation protocols for upper limb amputees. This highlighted the need for overarching guidelines for upper limb rehabilitation from the acute phase through to independence and community reintegration. Through working group discussions, the key elements of rehabilitation prescription, adaptations, re-training and best practice through multidisciplinary approaches will be emphasised. The use of technology and VR demonstrates an interactive and engaging approach to rehabilitation and will show the changes in rehabilitation that are possible.

DISCUSSION AND CONCLUSION
The creation of global standards of upper limb amputation rehabilitation guidelines will be a positive development in the prosthetic and orthotic sector by ensuring that upper limb amputees receive systematic evidence based, yet individual wholistic approaches to their rehabilitation experience. The use of technology and VR will enrich the field of rehabilitation creatively and assist upper limb amputees to return to activities of daily living and advanced functional training with the use of their final prosthesis.

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ACKNOWLEDGEMENTS: European Union Horizon Fund 2020.

2.5.1.d

Performance Evaluation of Bowden Control Cable Operation Recorder for Body-Powered Upper Limb Prosthesis

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BACKGROUND

Bowden Cable Control (BCC) System enables feedback control of terminal device open angle and pinch force by sensing the cable movement and tensile force from harness. The BCC is sufficient for dexterous tasks, however, is affected by the friction which alters individually and dynamically. The system's characteristic is experimented with a benchtop setup and a wearable system. Transmission efficiency, pinch force, execution time are reported [1], yet, precise instrumentation and assessment during task performance is needed to assess the system.

AIM

This research targets to develop an instrumentation device and evaluate the performance of the device by installing sensors and comparing the BCC operation of quasi-transradial body powered prosthesis.

METHOD

A control cable operation logger was developed. A strain-gauge-based load cell and potentiometer-based rotation angle meter were designed. The loadcell weighed 3.8g and measurable maximum force was 59N. The angle meter weighed 39g and the pully with the wire wound placed parallel to the control cable measured the travel up to 75mm. The sensors were connected to a portable mini-PC with 32GB SD memory card. By sampling at 20Hz, the device recording time was 6 hours. The logger was connected to a body-powered upper limb prosthesis simulator to operate Hosmer 5XA and recorded the operation to pick-carry-place clothes pins. The experiment was conducted after IRB approval and consent of the subject.

RESULTS

A set of three types of clothespin [small (pinch force 11.4N, grip distance 35mm), middle (11N, 60.4mm), and large (18N, 77mm)] placed on a bar in front of the body was moved to a height of 174, 296, 496 mm. Single able-bodied male subject, height 174 cm, performed the task 5-times each for the conditions after initial adjustment. The mean and S.D. of the recorded maximum tension and cable travel were 54.5±SD0.8N and 20.8±SD0.8mm for the small pin, 57.4±SD0.2N and 32.4±SD1.3mm for the middle pin, 58.9±SD1.8N and 41.8±SD2.4mm for the large pin. On comparing the performance between the pins, integral of the total work, which is the summation of the multiplication of travel and tensile force, was computed and analysed with Tukey's test showing the differences were significant.

DISCUSSION AND CONCLUSION

The maximum tensions were similar among the clothespins. The similarities were due to the rubber band's resistance at opening. The cable travels were different within the carrying heights and clothespins. The arm postures at each height and the pins' grip distance to open the hook caused the difference. These results indicate the recorder has appropriate resolution and is appropriate for evaluation of body powered system. Further tests are required with multiple subjects and body-powered prosthetic components.

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2.5.1.e
Extraneural Recordings Enable the Decoding of Intrinsic Hand Movements in Transhumeral Amputations

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BACKGROUND
Myoelectric prostheses restore limited hand function to individuals with upper limb amputation. The lack of prosthetic finger control indicates that there is a long way for prosthetic hands to be comparable to a biologic hand. Recent studies showed that primitive sensory feedback can be restored via extraneural electrodes placed around the nerves[1,2]. However, the capability of extraneural electrodes, such as cuffs, to record extraneural signals usable for decoding hand movements has not been demonstrated.

AIM
To investigate the feasibility of using extraneural signals to decode intrinsic hand movements in upper limb amputations.

METHOD
In three participants with transhumeral amputations, electroneurographic (ENG) signals were recorded using implanted cuff electrodes optimized for recordings[3]. Electromyographic (EMG) signals were also recorded using two implanted electrodes in the biceps and triceps muscles[1]. Participants trained the execution of phantom movements with a simple graphical interface showing the magnitude of each ENG signal in real-time. The training aimed at allowing the participants to identify how to execute movements resulting in ENG activity related to the executed phantom movements. Participants were then asked to execute four gross arm movements (hand open and close, and elbow flexion/extension) and up to five finger movements related to the recorded nerve (ulnar or median).

RESULTS
Offline analysis showed that intrinsic hand movement discrimination errors using ENG signals alone for 3 participants were 17%, 21.8%, and 16%, and when only EMG signal used it was 27%, 40%, and 13%. The error was reduced to 2%, 17.5%, and 4% when ENG and EMG signals were combined. This finding was consistent with the real-time performance, where the classification error of EMG + ENG was significantly lower than EMG or ENG alone ($p<0.01$). Our findings indicate that the combination of ENG and EMG signals can be used to decode hand and finger movements in individuals with transhumeral amputation.

DISCUSSION AND CONCLUSION
One major unsolved problem in prosthetics is to effectively use neural signals to enable the control of artificial limbs. Our results suggest that ENG signals recorded by cuff electrodes can be a valuable source of information for decoding intrinsic hand movements at transhumeral amputation levels. However, the reliability of such ENG-based control still needs to be tested in daily life, which requires specialized electronics as ENG signals are considerably smaller than EMG.

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Symposium
Education

2.5.2
Challenges and Opportunities: P&O Education During the Covid-19 Situation

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Abstract
The Covid-19 pandemic has forced academicians to rethink traditional prosthetic and orthotic instructional methods. In an effort to protect patients, students and faculty alike, programs have redesigned didactic and clinical practicum methods in order to provide a safe educational environment. This course highlights the methods and techniques employed in delivering prosthetics and orthotics instruction during this harrowing time. Description of online Learning Management System (LMS), Educational Technology (ET) as well as discussion of what works and does not work will occur.

Statement of the learning objectives
To provide attendees with a diverse perspective of challenges and opportunities to prosthetic and orthotic education during the COVID-19 situation. Strategies implemented to support safe and effective online and hybrid in-person education will be discussed.

Advanced Instructional Course
Developing Countries

2.5.3
Conducting Worthwhile P&O Research in Low-Resource Settings: What Constitutes Good Research, and a Good Outcome?

Cheryl Metcalf[1,2], Chantel Ostler[3,2], Maggie Donovan-Hall[1,2], Sisary Kheng[4], Cornelia Barth[5]

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Abstract
The global need for Prosthetic and Orthotic (P&O) devices is well-established, as is the shortfall in access to services, estimated at ~90% (WHO), especially in lower and middle income countries. Research will play a central role in delivering the changes needed to improve P&O service quality and access, but a “lack of ‘gold standard’ research guidance has led to poorly designed clinical and implementation studies that lead to inconclusive results and little guidance for market actors” (AT2030, 2020). Fundamentally, we need to identify what constitutes a good outcome of research. This Instructional Course will present a framework and experiences of trying to deliver ethical, sustainably-translatable LMIC P&O research, including:

- principles for ethical conduct of research, including obligations upon the researchers to minimise risk, obtain ethical approval, obtain informed consent, cover research costs, and demonstrate compliance with device structural integrity standards;
- awareness of barriers to conducting research, and designing research to overcome them;
- importance of creative, flexible, multi-stakeholder qualitative work to define research scope, identified as a key tool to ensure research focuses on lived experience of service users and their long-term outcomes (Editorial, *POI* 43(4), 2019); and
- identification of research data requirements, to address key questions: How can we solve a disconnect between clinical services and the data collection? What data would be meaningful to collect for all stakeholders? How should we analyse and use it to direct improvement, and how should we change direction if needed?

We will poll the audience throughout, to work towards a consensus report.

Statement of the learning objectives
This course will benefit clinicians and service providers participating in and consuming research; engineers designing ethical, objective tests of technologies; and service users the results belong to, and with whom they should be shared appropriately.

Free Paper Session
Prosthetics: Lower Limb – Prosthetic Feet and Alignment

2.6.1.a
Hip Trajectory Error Framework for Designing Prosthetic Feet for a Passive Prosthetic Knee

Nina Petelina, Amos Winter

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BACKGROUND
The performance of an above-knee amputee's prosthetic leg depends on the performance of the prosthetic foot. An inadequate prosthetic foot promotes compensatory behaviour that can result in serious health issues. Lower Leg Trajectory Error (LLTE) is a framework that facilitates the design of low-cost energy storage and return prosthetic feet and has shown close replication of able-bodied lower limb kinetics and kinematics for studies with below-knee amputees [1, 2].

AIM
The aim of this work is to create a framework for designing and evaluating prosthetic feet performance for transfemoral amputees using a passive prosthetic leg and comparing performance to a prosthetic foot designed using the LLTE framework.

METHOD
Hip Trajectory Error (HTE) is a proposed framework for prosthetic foot design that maps the mechanical design of a prosthetic foot to its biomechanical performance. As with the LLTE, the inputs to HTE frameworks are the ground reaction forces and centre of pressure locations from able-bodied data. Both frameworks predict how the foot will deform under the expected loading conditions. The LLTE framework optimizes the location and orientation of the lower leg, whereas the HTE optimizes the hip location to match a reference trajectory. Two prosthetic feet models were optimized for the same subject, one using LLTE framework and one using HTE framework.

RESULTS
The resulting modelled hip motion for a passive prosthetic knee that does not flex during stance phase for each model was calculated. The hip motion for the LLTE-optimal foot was approximated as the extension of the lower leg. The error for each model was calculated by comparing hip trajectory to reference able-bodied data. The HTE-designed foot achieved a closer replication hip trajectory than the LLTE-designed foot. This result suggests that a prosthetic foot designed for a transtibial amputee would not result in an optimal performance for a transfemoral amputee.

DISCUSSION AND CONCLUSION
Hip Trajectory Error is a framework for designing prosthetic feet for above-knee amputees that optimizes the hip trajectory. Since passive prosthetic knees commonly do not flex during early stance, it could be beneficial for the prosthetic foot to perform shock absorption by promoting able-bodied pelvic obliquity [3]. Achieving close-to-able-bodied hip motion can potentially improve gait symmetry and, therefore, prosthetic leg performance.

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ACKNOWLEDGEMENTS: Funding provided by NSF Career Award (no.1653758).

2.6.1.b
Mobile Technology for Objective Prosthetic Alignment

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BACKGROUND
Alignment of the lower limb prosthesis critically affects a person's functional performance and comfort, by altering the manner in which the weight-bearing load is transferred between the residual limb and the walking surface [1,2,3,4]. Current alignment adjustment processes require prosthetists to repetitively observe gait and then make relatively imprecise angular and translational adjustments by feel. Research has demonstrated that prosthetists using manual alignment devices were not able to accurately control adjustments they made [5].

AIM
The purpose of this work was to develop and validate novel instrumentation, mobile application, and methods that enable prosthetists to efficiently and objectively adjust prosthetic alignment to achieve optimal user gait.

METHOD
We developed a Prosthetic Smart Alignment Tool (ProSAT) to facilitate rapid, accurate, controllable adjustment of the prosthesis physical alignment. The ProSAT system consists of an embedded modular Gait Sensor prosthetic component and a wirelessly connected Smart Alignment Tool that both link to an alignment expert system mobile application.

Bench testing validated the ProSAT system measurements on a prosthetic socket. The prosthesis foot was removed, and the shank rigidly connected to a base. Four different prerecorded test adjustments that required correction were used. Custom software directed the tester to physically change the socket alignment and recorded sensor and position data as alignment changed.

RESULTS
Measurements of the ProSAT tool were compared to measurements from a coordinate measuring machine. The coordinates of the 3-dimensional movement of the prosthetic socket were measured Pre and Post adjustment of two fiducial points marked on the anterior surface of the socket. The Cartesian coordinates provided by the coordinate measuring machine were used to derive an angle from vertical for the Pre and Post alignment conditions. The ProSAT tool only controls the relative change made to the alignment, not an absolute position or orientation. All alignment changes with the ProSAT tool were made only using the feedback from the mobile application software. The bench testing demonstrated that the user could successfully and quickly achieve target alignment change within an average of 0.1 degrees.

DISCUSSION AND CONCLUSION
The accuracy of the ProSAT system has been validated and demonstrates the system's readiness for a clinical trial to evaluate alignment efficiency, accuracy, and user experience. Refinement of ergonomic form and technical function of the hardware and clinical usability of the software are being completed prior to conducting the clinical trial. The ProSAT system helps prosthetists diagnose and guide the correction of very subtle, difficult-to-see imbalances in prosthesis user gait.

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2.6.1.c

Effects of Angular Changes of the Prosthetic Feet of Transtibial Prostheses on Socket Reaction Moments

Hiroshi Hashimoto[1,2], Toshiki Kobayashi[3], Masataka Kataoka[2], Kuniharu Okuda[2]

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BACKGROUND

Socket reaction moment (SRM) has been reported to have a systematic relationship with alignment changes of transtibial prosthetic sockets. Therefore, SRM may be useful to evaluate prosthetic alignment quantitatively. However, the effects of alignment of the prosthetic feet on SRM is still unclear.

AIM

To investigate whether alignment changes of the prosthetic feet (plantarflexion, dorsiflexion, inversion, and eversion) influence SRM systematically in the sagittal and coronal planes.

METHOD

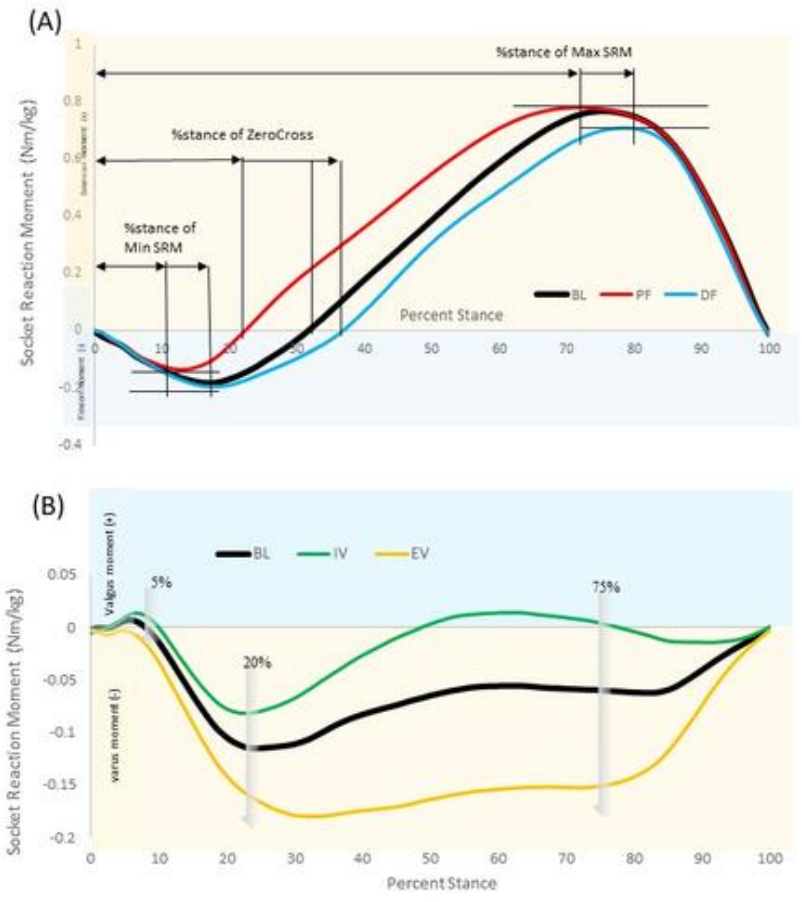
Ten users of transtibial prostheses were recruited in this study. Temporal-spatial parameters (Cadence, walking speed, step time, single support time, and step length) and sagittal and coronal SRM were measured during walking under five alignment conditions (3-degree plantarflexion and dorsiflexion, 6-degree inversion and eversion, and baseline alignment. Minimum and Maximum SRM, % stance (timing) of Minimum and Maximum SRM and zero cross in the sagittal plane, SRM of 5% stance, 20% stance, and 75% stance in the coronal plane were extracted and analysed. Repeated measures of ANOVA or Friedman tests were carried out for statistical analyses ($p < 0.05$).

RESULTS

In the coronal plane, SRM of 5% stance, 20% stance, and 75% stance showed significant differences under both inversion and eversion (p=0.018, <0.001, <0.001, respectively). Minimum SRM, % stance of Minimum and Maximum SRM, and zero cross showed significant alignment changes (plantarflexion / dorsiflexion) (p=0.028, 0.017, <0.001, respectively). There were also significant differences among single support times of the intact side in sagittal alignment changes, step time of the prosthetic side and single support times of the intact side with relation to coronal alignment changes.

DISCUSSION AND CONCLUSION

Our findings suggest that inversion and eversion of transtibial prosthetic feet would affect the magnitude of SRM systematically in the coronal plane, while plantarflexion and dorsiflexion would affect the timing of SRM and Minimum SRM in the sagittal plane. These findings may be beneficial to evaluate and adjust alignment of feet in transtibial prostheses.



(A) : Socket reaction moment in the sagittal plane.
(B) : Socket reaction moment in the coronal plane.
Abbreviation: BL: baseline, PF: plantarflexion, DF: Dorsiflexion, IV: Inversion, EV: Eversion.

2.6.1.d

A Randomised Feasibility Study of a Self-Aligning Prosthetic Ankle-Foot for Older Patients with Vascular-Related Amputations: The STEPFORWARD Study

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BACKGROUND

In the UK, the majority of amputations are transtibial, a result of diabetes and/or vascular disease, and in patients over 50 years [1]. Many older patients are prescribed a standard prosthesis with an ankle-foot that is not self-aligning. These types of prostheses are designed for level walking, and do not adjust to sloped surfaces. A self-aligning prosthesis, designed for everyday environments and for patients categorised as having 'limited community mobility' (K2), is available on the NHS, but seldom prescribed.

AIM: This multi-centre, randomised controlled trial assessed the feasibility of conducting a full-scale trial of the effectiveness and cost-effectiveness of a self-aligning prosthetic ankle-foot for older patients compared with a standard prosthetic ankle-foot.

METHOD

We aimed to recruit 90 participants aged ≥ 50 years with a vascular-related or non-traumatic unilateral transtibial amputation for ≥1 year, categorised as having 'limited community mobility', and using a non-self-aligning prosthetic ankle-foot. Participants completed a baseline assessment including four clinical tests and questionnaires and wore an activity monitor on their normal prosthesis for one week. They were then randomised into one of two groups for 12 weeks: self-aligning prosthetic ankle-foot or existing standard prosthesis. Participants completed the same questionnaires at the interim follow-up and the full set of baseline assessments at final follow-up. Feasibility measures included recruitment, consent and retention rates; and completeness of clinical tests and questionnaire datasets.

RESULTS

Fifty-five participants were randomised (61% of the target 90 participants): n=27 self-aligning ankle-foot group, n=28 standard prosthesis group. Their mean (SD) age was 68.8 (9.6) years. Fifty-one participants were included in the final analysis (71% of the target number of participants). The consent rate and retention at final follow-up were 86% and 93%, respectively. The average recruitment rate was 1.25 participants/site/month (95% CI 0.39 to 2.1). Completeness of questionnaires ranged from 89-94%, and clinical tests were 92-95%, including the activity monitor data. The average completion rates for the data ranged from 63% to 93%. Of the clinical tests, only the 2-minute walk test appeared to show a change between baseline and final follow-up. Participants with the self-aligning prosthetic ankle-foot walked on average 6.2 (16.2) metres further while participants in the standard prosthesis group walked 9.0 (29.8) metres less.

DISCUSSION AND CONCLUSION

This feasibility trial recruited and retained participants who were categorised as having 'limited community mobility' following a transtibial amputation. The high retention rate of 93% indicated the trial was acceptable to participants and feasible to deliver as a full-scale RCT. The findings support a future, fully-powered evaluation of the effectiveness and cost-effectiveness of a self-aligning prosthetic ankle-foot compared to a standard non-self-aligning version with some adjustments to the trial design and delivery.

Table 1. Mean (SD) clinical tests and questionnaires at baseline and final follow-up, by trial arm

	Baseline		Final	
Clinical tests	Self-aligning	Standard	Self-aligning	Standard
2mWT (m)	81.0 (31.4)	94.7 (33.5)	88.8 (40.0)	83.9 (41.5)
BBS (score/56) *	39.5 (11.3)	42.9 (8.1)	40.7 (12.9)	39.4 (11.6)
TUDS (s)	61.4 (33.0)	66.9 (38.5)	59.2 (29.2)	68.1 (56.7)
TUG (s)	20.8 (15.2)	21.3 (23.5)	21.0 (19.1)	17.8 (8.4)
Daily steps (#)	1756 (1964)	1751 (1370)	1673 (1594)	1836 (1648)
Daily stepping (min)	29.9 (30.8)	31.1 (24.9)	27.7 (24.0)	31.2 (25.8)
Questionnaires				
LCI-5 (score 0-56) *	36.4 (12.0)	39.6 (11.2)	37.8 (11.4)	39.2 (11.2)
Houghton (score 0-12) *	7.8 (2.0)	8.8 (1.8)	8.3 (1.9)	8.5 (2.0)
PROMIS 3a pain intensity **	41.3 (10.0)	43.1 (9.5)	40.4 (9.4)	42.7 (8.7)
PROMIS 8a pain interference **	52.8 (11.2)	51.7 (9.4)	51.2 (11.4)	53.3 (10.0)
EQ-5D-5L utility score *	0.62 (0.3)	0.63 (0.35)	0.75 (0.16)	0.63 (0.32)

2mWT: 2-minute walk test; BBS: Berg Balance Score; LCI-5: Locomotor Capabilities Index-5;
PROMIS: Patient Reported Outcomes Measurement Information System;
TUDS: Timed Up and Down Stairs Test; TUG: Timed Up and Go Test
* Higher scores indicate better performance ** A higher PROMIS T-score represents more of the concept

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ACKNOWLEDGEMENTS: This paper presents independent research funded by the National Institute for Health Research Research for Patient Benefit Programme (ref: PB-PG-0816-20029).

2.6.1.e

How a Systematic Variation of Prosthetic Foot-Ankle Stiffness Affect Gait and Balance in People with Unilateral Transtibial Amputations

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BACKGROUND

Modular prosthetic ankle components have been shown to improve walking in transtibial prosthesis users, but they may reduce stability during standing. Therefore, the stiffness of the prosthetic foot-ankle components may need to be appropriately tuned to provide optimal balance between mobility for walking and stability for standing. The present research investigates both concepts to improve our knowledge about how the prosthetic ankle stiffness influences standing and walking performance.

AIM

Two aims were addressed:

- To determine the effects of different prosthetic ankle stiffness on gait biomechanics of unilateral, transtibial prosthesis users.
- To determine the effects of different prosthetic ankle stiffness on quiet standing balance of unilateral, transtibial prosthesis users

METHOD

Subjects: A diverse group of ten individuals with unilateral transtibial amputation and categorized as K3 level of ambulation participated.
Apparatus: Kinematic and kinetic data were collected using a digital motion capture system (Motion Analysis Corp, CA) and force platforms in the JBVAMC Motion Analysis Research Laboratory.
Procedures: Gait and balance analysis were performed at three different levels of ankle dorsiflexion stiffness (firm, medium and soft) using the College Park Venture foot (College Park, MI).
Data Analysis: Data were grouped and analysed accordingly. Repeated measurements ANOVA were performed for the temporal-spatial, quiet standing and Roll-Over Shape (ROS) values. Kinetic and kinematic data were analysed using a one-dimension statistical parametric analysis.

RESULTS

The results suggest an influence of foot-ankle stiffness on gait and balance, especially on ROS radii and movement of centre of pressure (COP). The analysis of ROS radii indicates significant differences due to stiffness condition [$F(2,98)=38.622$, $p<0.001$] and walking speed [$F(2,98)=24.522$, $p<0.001$]. Pairwise comparisons indicated significant differences between all three levels of stiffness ($p<0.001$) and between slow and fast walking speeds ($p<0.001$). On quiet standing, at the eyes closed condition, movement of COP demonstrated a significant difference [$F(2,58)=8.044$, $p=0.003$] based upon bumper durometer. Moreover, the pairwise comparison indicated a difference between Firm and Soft bumpers ($p<0.001$).

Figure 1. Radius of ROS (Normalized) at different stiffness conditions and self-selected walking speeds

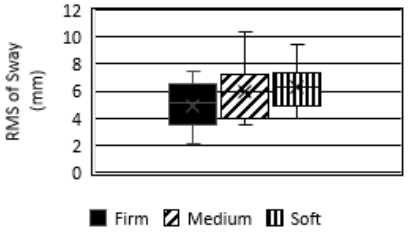

Figure 2. Root Means Square Distance of Sway during quiet standing at different stiffness conditions.

DISCUSSION AND CONCLUSION

Anatomical ankle stiffness has been reported to adapt to different walking speeds to maintain a uniform ROS radius (Hansen et al., 2010), contrary to our data that indicate prosthetic ankle components with constant stiffness produce different ROS radii at different speeds.
The Firm stiffness was able to best replicate the able-bodied individuals' ROS radius and appeared to provide the most advantages during walking and quiet standing.

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ACKNOWLEDGEMENTS: This study was supported by Veterans Health Administration Rehabilitation Research and Development Service (grant no. RX002107).

Symposium
Education

2.6.2
Latest Developments in ISPO P&O Educational Activities, focusing on the New ISPO Education Standards, GEM2022, COVID-19 and Blended Learning

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Abstract
ISPO plays an important role in P&O education globally. This presentation will provide an overview of the implementation of the ISPO Education Standards and accompanying procedure to date. Since their release, multiple accreditations have taken place and challenges including COVID-19 have been experienced. This presentation aims to communicate the outcome of these experiences.

Planning for the third Global Educators Meeting to be held in Thailand (June 2022) is moving ahead. For the first time this event will have a blended approach with on-site and virtual presentations and participants. Information on the event is available on the ISPO website.

A survey was sent to P&O schools around the globe to learn about the effects, adjustment and support needs during the COVID-19 situation. Twenty-two schools from 20 countries responded; most schools were affected, but able to achieve institutional goals with an average 50% adjustment to overall program structure. The top three needs identified were teaching staff training, advice on blended and distance learning, and student training.

Education in P&O demands a good methodology and didactic model. For practitioners on the job, access to formal education is often an insurmountable obstacle. The experience of Blended Learning methodology in P&O education presents a relevant pathway for Continuous Professional Development (CPD) as well as for formal education in an ever-changing professional environment and different context.

Statement of the learning objectives
Attendees will gain an understanding of the new ISPO education standards through accreditation audits in 2021, plans for GEM2022, the ISPO survey on the impact of COVID-19 on P&O education programs and blended learning.

Free Paper Session
Gait and Balance: Ambulatory Capacity and Balance

2.6.3.a
Comparison of Ambulatory Capacity Between Vascular and Traumatic Transtibial Amputees

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BACKGROUND
There is a potential deterioration of gait and balance in lower limb amputees in comparison to able bodied subjects[1]. Gait and balance of amputees could be affected by age, amputation level and type of prostheses[2,3]. However it is not clear whether the reason of amputation affects ambulatory capacity in transtibial amputees because of the heterogeneity of amputees and prostheses included in the studies[4,5].

AIM
To compare ambulatory capacity between vascular and traumatic transtibial amputees.

METHOD
Thirty-one unilateral transtibial amputee, having the ability to walk 30 meters independently and using the prostheses for at least six months, participated in the study. Gait capacity was assessed with a 2-minute walk test (2MWT) in terms of distance. Timed Up & Go (TUG) and Functional Reach (FR) tests were used to assess balance and also Activities Specific Balance Confidence Scale (ABS) was completed by the participants. Because body mass indexes were found to be different between groups, this variable was controlled in the analysis by using General Linear Model and observed power (β) was calculated for outcome measures. The research procedure was approved by the local ethical committee and all participants signed an informed consent form.

RESULTS
Age, gender and types of prostheses were similar between groups (p>0.05). However, BMI was higher in the vascular group (p<0.05). TUG, ABS and 2MWT results were found to be better in the traumatic group (p<0.05, Table 1).

Table 1. Comparison of results between groups.

		Vascular (n=16)	Traumatic (n=15)	p	β
Age (years, X ± SD)		59.8 ± 9.5	55.6 ± 6.4	0.085	
Gender (n)	**Male**	13	14	0.316	
	Female	3	1		
Prosthesis (n)	**Elevated vacuum & carbon foot**	11	11	0.779	
	Pin suspension & dynamic foot	5	4		
BMI (kg/cm^2, X ± SD)		30.6 ± 4.3	25.9 ± 3.3	**0.001***	
Years of amputation (X ± SD)		5.3 ± 4.4	19.8 ± 16.8	**0.006***	
2MWT (meters) (X ± SD)		76.3 ± 35.8	97.7 ± 30.5	**0.012***	0.73
TUG (sn) (X ± SD)		14.4 ± 9.5	8.9 ± 2.1	**0.013***	0.72
FR (cm) (X ± SD)		31.0 ± 6.6	34.0 ± 9.5	0.081	0.41
ABS (%)		75.5 ± 16.4	87.7 ± 9.9	**0.032***	0.58

*p<0.05

DISCUSSION AND CONCLUSION
Traumatic transtibial amputees were found to have better balance confidence, balance and ambulation skills than vascular ones. This result confirms that the vascular amputees have worse ambulatory capacity probably as a result of their comorbidities. Physiotherapists should aim to improve balance and gait skills especially of vascular amputees in order to prevent potential future falls.

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2.6.3.b
Falling Rate and Pain Prevalence Among Lower Limb Amputees Based on Real World Data

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BACKGROUND
Falls and pain are common among lower limb amputees; they are however influenced by many factors. To obtain plausible results, data collected from a high number of amputees should be analysed. Therefore, many research questions remain unanswered.

AIM
To investigate whether data collected in a multinational prosthetic outcome registry ("Registry") during routine prosthetic interventions are valid to be used for further research on pain and falls among lower limb amputees.

METHOD
The data in the Registry reported by amputees already having a prosthesis before the considered intervention have been analysed. Only unilateral major amputations were included. For each subject pain intensity (0 = no pain; 10 = most imaginable pain) in back, residual and sound limb, as well as intensity of phantom pain, were evaluated.

RESULTS
The data are from 18 clinics in 7 countries. Amputation Levels: 7 HD, 189 TF, 31 KD, and 235 TT. 24% were female and 50% were mobility grade 3. Mean age: 47±18 years.

There were statistically significant differences between the falling rate during six months preceding the measurement depending on the amputation level ($\chi2(6)=48.536$, $p = 0.000$). No fall was reported by 43% HD, 52% TF, 19% KD and 74% TT. More than one fall in that period was reported by 57% HD, 33% TF, 55% KD and 14% TT.

17% of amputees have reported that they have no pain at any of the three locations under consideration (excluding phantom pain). This ratio was lowest (6%) for KD. Median phantom pain intensity for all amputation levels was higher than median pain in other locations (see figure 1).

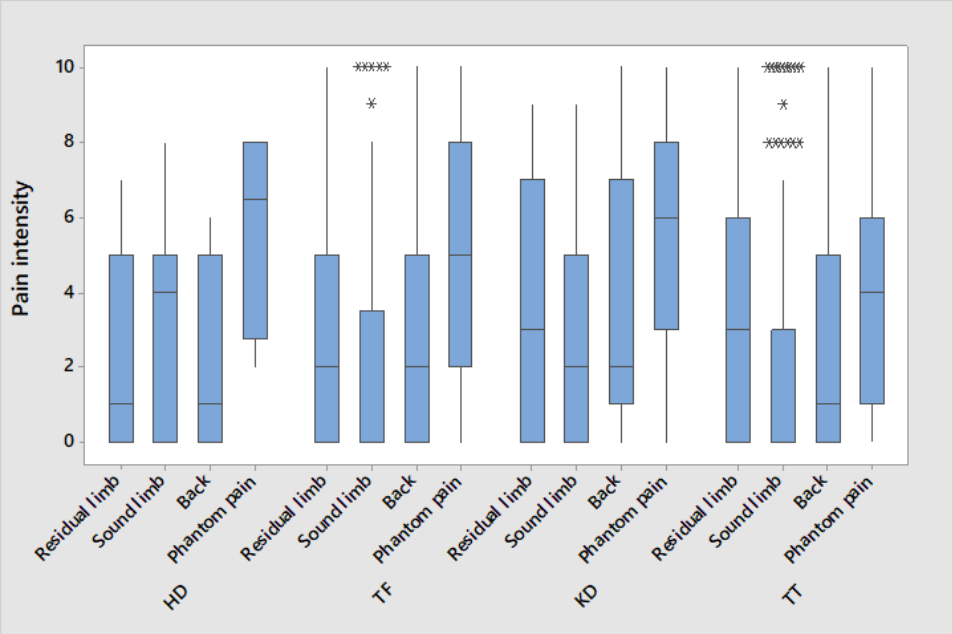

Figure 1. Distribution of the reported pain intensity depending on the amputation level and pain location.

DISCUSSION AND CONCLUSION
The observations on falling rate are consistent with the findings in [1], except that a high frequency of falls by KD was observed. Our findings on pain prevalence are comparable with those in [2].
The fact that the data in our study, despite the high number and the variability of the study sites, are coherent with the data collected in the high-quality studies, confirms that the data from the Registry constitute a solid basis for further research on this topic.

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2.6.3.c

Step Length Asymmetry is Associated with Fear of Falling Activity Avoidance in Persons with Unilateral Transtibial Amputation

Noah Rosenblatt

Rosalind Franklin University of Medicine and Science, North Chicago, USA

BACKGROUND

Low balance confidence and fear of falling (FoF) are prevalent issues among prostheses users [1] that can significantly limit activity. To our knowledge no studies have evaluated gait characteristics specific to persons with transtibial amputation (pTTA). Common gait asymmetries in pTTA, e.g., greater prosthetic step length (SL), may represent a functional adaptation to maintain stability [2], and not a negative consequence of amputation.

AIM

The study aimed to evaluate the association between i) step length asymmetry (as well as other symmetry indices) and ii) measures of balance and gait self-efficacy as well as FoF-related activity avoidance.

METHOD

Seventeen pTTA participated. Participants walked across a 10m walkway at a self-selected pace. For each limb, motion capture quantified: SL; step width (SW); step time (ST); percent single support (%SS); single support time (SST); percent double support (%DS) and double support time (DST). Symmetry indices (SI) were calculated based on across-step averages. Participants also completed: i) Activity-specific Balance Confidence (ABC); ii) Modified Gait Self Efficacy Scale (mGES); iii) Fear of Falling Avoidance Behaviour Questionnaire (FFABQ); iv) One item from the PEQ - "Over the past 4 weeks, rate how satisfied you have been with how you are walking". Correlational analyses were conducted.

RESULTS

Prosthetic-side SL was significantly associated with all survey measures (Table 1). However, only FFABQ, was associated with SL SI. Neither limb-specific measures nor SI measures for SW, ST, % SS, %DS or DST were significantly associated with any survey measures. However, SST SI was significantly associated with ABC and the PEQ walk item (Figure 1); greater prosthetic relative to intact (positive SI) was associated with greater confidence and gait satisfaction.

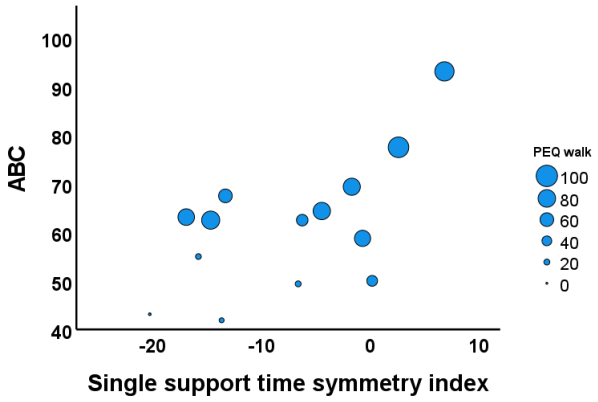

Figure 1. ABC vs. SST SI; bubble size relative to PEQ question.

DISCUSSION AND CONCLUSION

Longer prosthetic side steps (reliant on intact push off) and longer relative prosthetic SST (reliant on prosthetic-side balance) may promote self-efficacy and limit FoF-related activity avoidance. Fostering symmetry in rehabilitation may not be desirable outcome.

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ACKNOWLEDGEMENTS: This work was funded by DoD award W81XWH-17-1-06.

2.6.3.d

Functional Outcomes and Fears of Falls in Through-Knee Amputations Compared to Above-Knee Amputations: A Systematic Review and Meta-Analysis

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[1]Academic Vascular Surgical Unit, Hull York Medical School, Hull University Teaching Hospitals NHS Trust, Hull, United Kingdom. [2]Department of Sport and Exercise Sciences, University of Hull, Hull, United Kingdom

BACKGROUND

Through-knee amputation (TKA) represents less than 1% of all major amputations in the UK[1]. As such, patients suitable for TKA or above-knee amputation (AKA) may be receiving AKA despite potential functional advantages of a TKA. Advantages may include preservation of thigh muscles, a longer mechanical lever arm and an end weight-bearing residual limb[2,3] and could benefit non limb wearers as well as prosthetic users.

AIM

The aim of this systematic review was to compare the gait, biomechanical and functional outcomes of TKA and AKA, and to examine their fears of falling.

METHOD

CINAHL, Embase Medline, PubMed, Cochrane and ClinicalTrials.Gov databases were searched for terms relating to TKA, AKA and mobility. All studies including randomised clinical trials comparing unilateral and bilateral TKA and AKA were included. Studies were excluded if they were qualitative and if there was no separation of TKA data. Outcome measures were walking speed, temporal-spatial parameters, kinematic and kinetic parameters, timed walking tests, fear of falling, level of prosthetic ambulation, and distance walked. The risk of bias was assessed using the Risk of Bias in Non-Randomised Studies (RoBANS) tool and study quality using the Downs and Black checklist.

RESULTS

Twenty-four articles were included in the review. Walking speed was reported in seven papers and was increased in TKA compared to AKA (Table 1), but a meta-analysis did not reach significance (p=0.59). TKA had an increased walking distance during the six-minute walk test (6MWT) in two papers, but a meta-analysis showed no significance (p=0.29). Two-minute walk test (2MWT) and Activities-Specific Balance Confidence Scale (ABC) were reported in two papers and were contrasting in results, but a meta-analysis suggested no significant difference (p=0.44 and p=0.52, respectively).

Table 1. Outcome Measures

Articles	**Outcome Measures**				
	2MWT	6MWT	Walking Speed	ABC-UK	LCI-5
Alsancack et al.			↓		
Goksenoglu et al.					↓
Jeans et al.			↑		
Karatzios et al.	↓		↓	↓	↔
Moller et al.		↑	↑	↑	
Pinzur et al.			↑		
Reid et al.	↑	↑	↑		
Schuett et al.			↔		
Key: Locomotor Capabilities Index-5 (LCI-5). ↑ TKA greater than AKA; ↓ AKA greater than TKA; ↔ TKA and AKA similar.					
Meta-Analysis	✓	✓		✓	✓

DISCUSSION AND CONCLUSION

Identified studies are limited by small numbers of participants and heterogeneous methods, precluding meta-analysis of most of the available data. Literature suggests that TKA may provide functional benefits (walking speed) over AKA during daily living, but fear of falls and other outcomes are less consistent. Future work focusing on determining the functional differences between TKA and AKA is important as this may influence surgical decision making regarding the most appropriate level of amputation if patients are suitable for either procedure.

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2.6.3.e

Relationship Between Level of Daily Activity and Upper-Body Aerobic Capacity in Adults with a Lower Limb Amputation

Mirjam Mellema[1,2], Peyman Mirtaheri[3], Terje Gjøvaag[1]

[1]Faculty of Health Sciences, Oslo Metropolitan University, Oslo, Norway. [2]Faculty of Technology, Art and Design, Oslo Metropolitan University, Oslo, Norway. [3]Faculty of Technology, Art and Design, OsloMet - Oslo Metropolitan University, Oslo, Norway

BACKGROUND

Previous studies show that people with lower limb amputation (LLA) have a sedentary lifestyle,[1] reduced walking capacity, and lower cardiorespiratory fitness.[2] Physical inactivity is associated with a decline in cardiorespiratory fitness and an increased risk of cardiovascular disease and all-cause mortality in the general population. In people with LLA, there is evidence showing that aerobic capacity (VO_2peak) is an important determinant for walking capacity,[3] but the relationship between VO_2peak and physical activity level in daily life remains unknown.

AIM

To investigate the relationship between upper-body aerobic capacity, objectively measured levels of physical activity, and walking capacity in persons with LLA.

METHOD

Fourteen persons (two females) with unilateral LLA on the transtibial (n=7), transfemoral (n=5) and knee-disarticulation (n=2) levels participated in the study. Mean ± SD age and time since amputation was 55.7 ± 10.1 and 20.5 ± 18.0 years, respectively. Participants performed assessment of VO_2peak on an arm-crank ergometer and walking capacity (preferred walking speed (PWS) and Two Minute Walking Test (2MWT)). Level of physical activity was measured over seven days with a Step Activity Monitor (number of steps, sedentary time and proportion of low-, moderate-, high- and peak-intensity activity level). Pearson correlation analyses were performed without correction, and with correction for the variable age, since VO_2peak declines with ageing.

RESULTS

VO_2peak correlated significantly with number of steps per day ($r = .696$, $p = .006$), high-intensity activity level ($r = .769$, $p = .001$) and peak-intensity activity level ($r = .674$, $p = .008$). There was a significant large negative correlation between VO_2peak and sedentary time ($r = -.618$, $p = .019$). After correcting for age, correlations were still large and significant. Large correlations were also found between VO_2peak, PWS ($r = .586$, $p = .027$) and 2MWT ($r = .649$, $p = .012$).

DISCUSSION AND CONCLUSION

This is the first study to demonstrate the strong relationships between upper-body VO_2peak, sedentary behaviour, high-intensity activity level and walking capacity in persons with LLA. The results indicate that persons who exhibit less sedentary behaviour and perform larger proportions of high-intensity activity, have a higher upper-body cardiorespiratory fitness and a higher walking capacity. Further research is needed to investigate the potential effect of improving cardiorespiratory fitness on the ability for physical activity in daily life.

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Wednesday, 3 November

Keynote Lecture

3.0
Personalized Rehabilitation: Mapping the Links Between Prosthesis Parameters, Motor Capacity, and Clinical Outcomes for Optimizing Interventions

Matthew Major

Jesse Brown VA Medical Center Chicago USA. Feinberg School of Medicine Chicago USA. McCormick School of Engineering Chicago USA. Northwestern University Prosthetics-Orthotics Center (NUPOC) Chicago USA

Abstract

The selection of prosthetic device parameters to restore function of persons with lower-limb loss can be framed as an optimization problem to maximize a given performance outcome. The choice of particular outcomes, such as locomotor stability, comfort, or metabolic cost, is a shared decision amongst the rehabilitation team and patient, and depends on a patient's functional capacity and motivation.

Historically, the selection of prosthesis parameters to match components with patients has been constrained to those fixed mechanical properties of commercial devices. Classical comparative studies have suggested an effect of commercial prosthesis design on clinically-relevant outcomes, but these studies lack reliability and the results are often inconsistent.

However, recent parametric studies have begun to systematically probe the influence of prosthesis parameters (i.e., mechanical function) on performance outcomes through the use of novel methodologies and experimental prosthetic technology. Results from these parametric studies generate digital maps defining the relationships between select parameters (e.g., stiffness, damping, roll-over geometry) and a desired outcome. Moreover, these maps can be expanded into a multidimensional landscape when considering factors of patient motor capacity (e.g., muscle strength, sensory feedback) as an additional covariate. Through these correlate maps, parameter values can be identified that maximize a given performance outcome, thereby providing an objective framework to optimize prosthesis designs. Importantly, by accounting for person-specific variables pertaining to motor performance, this framework can yield predictions of performance outcomes for individual patients.

This review will discuss:

1) a selection of novel experimental techniques being implemented to populate these correlate maps, and

2) how an iterative optimization approach can deliver personalized lower-limb loss rehabilitation interventions when integrating targeted physical therapies that encourage self-organization with the prosthesis.

Advanced Instructional Course
Prosthetics: Upper Limb

3.2.1
Myoelectric Control Training Using a Flexible Physical and Virtual System

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Abstract
The capabilities of commercial myoelectric devices have been steadily improving; however, evaluating and training persons with amputation in using the technology remains challenging. As the level of amputation or complexity of the technology increases, it becomes more difficult to choose the control system and the number of controllable degrees of freedom. To address this challenge, we have designed a training system that includes a physical and virtual robotic arm with 5 degrees of freedom, an electromyography (EMG) acquisition system, an embedded controller, and a laptop with a graphical user interface for fine tuning EMG parameters such as gains and thresholds. The training system was successfully translated to two rehabilitation hospitals with other translations ongoing. The technologies, including the Bento Arm and brachI/Oplexus software, have been released under open-source licenses for accessibility. The clinical teams, which include a physiatrist, occupational therapist, and prosthetist, use the system to assess the number of degrees of freedom the patient can reliably control, to explore control strategy options, and to start training the patient earlier using functional control tasks. In this workshop we will demonstrate the use of both the physical and the virtual training arm and protocols used in two sites (Canada and Australia). We will present the benefits and limitations we have experienced over the last 5 years in use of the training tool, and engage attendees in discussion of facilitators and barriers to integrating early training systems into clinical practice.

Statement of the learning objectives
The objective of this workshop is to provide guidance on how physical and virtual robotic arm systems can be used for the assessment and training of individuals with upper limb amputation.

Free Paper Session
Orthotics: Device Fabrication and Design

3.2.2.a

The Effectiveness of Cranial Orthoses for Treatment of Deformational Plagiocephaly, Asymmetrical Brachycephaly and Symmetrical Brachycephaly: a Retrospective Clinical Audit

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BACKGROUND
There has been a substantial increase in non-synostotic (positional) cranial deformities in the past two decades [1-3]. Cranial orthotic treatment has proven to be a consistent method for the correction of positional cranial deformities. Treatment regimens, however, still persist to be under argumentative discussion, particularly in regards to the age at which cranial orthotic treatment is started [4-5].

AIM
The aim of this retrospective clinical audit was to investigate the effectiveness of cranial orthoses treatment and the impact of starting age, severity of asymmetry, and duration of treatment on improvement of cranial asymmetry and cephalic ratio.

METHOD
A total of 106 patients, treated at CureMed Tabsh Medical Centers with cranial orthoses for Deformational Plagiocephaly, Symmetrical Brachycephaly and Asymmetrical Brachycephaly, were included in this study. For diagnosis classification and treatment evaluation, Cranial Vault Asymmetry Index (CVAI), Cranial Vault Asymmetry (CVA), and Cephalic ratio (CR) measurements, obtained from a three-dimensional (3D) photogrammetry laser scanner, were used pre- and post-treatment. Patient cohort was divided based on starting age of cranial orthoses treatment (younger/older than 7.5 months), and treatment duration (more/less than 150 days). Furthermore, patients were classified by severity according to the Children's Healthcare of Atlanta's (CHOA) CVAI severity scales (normal; mild; moderate; severe; very severe).

RESULTS
Highly significant results ($p < 0.001$) were presented in the CVAI and CR difference measurements for all patients, before and after treatment. Patients younger than 7.5 months, had a significantly higher CVAI/CR correction rate ($p = 0.001$; $p = 0.013$), and the CVAI reductions within the two age groups, significantly differed in patients (more in the <7.5-month group) with moderate ($p = 0.014$) and severe ($p = 0.012$) deformities. Between the two duration groups, a significant difference was only shown in the CVAI measurements, in which the >150-days group had the better value ($p = 0.022$).

DISCUSSION AND CONCLUSION
This audit confirms that cranial orthoses are effective in the treatment of deformational cranial deformities. It is indicated that patients younger than 7.5 months, and with moderate or severe levels of severity, should start treatment at an earlier age, as it would ensure a more efficient outcome. Wearing cranial orthoses for a longer period of more than 150 days, is also more beneficial.

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3.2.2.b
Developing a Smart Ankle-Foot Orthosis to Improve Stroke Outcomes

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BACKGROUND
Ankle-foot orthoses (AFOs) are commonly prescribed to help minimize challenges of walking due to stroke. Current AFO fitting processes to optimize stiffness and alignment for each patient rely on observational gait analysis and trial-and-error adjustment, which is time-consuming and susceptible to variability. Our prior research revealed that post-stroke AFO users' gait data can be systematically correlated to sagittal AFO stiffness and range of motion [1], thus informing an integrated system design that dynamically evaluates gait data to guide AFO adjustments.

AIM
Our purpose was to develop a diagnostic wireless, smart ankle-foot orthosis system (Smart AFO) that assists clinicians in optimizing AFO stiffness and range of motion settings, and quantifying functional walking improvements in post-stroke individuals.

METHOD
An AFO with independent ankle range of motion and stiffness adjustments in plantarflexion and dorsiflexion (Becker Orthopedic, Troy, MI) was instrumented with sagittal moment and ankle angle sensors to wirelessly stream real-time sensor signals via Bluetooth to a custom mobile application (App). A step detection algorithm was developed and implemented in the App. Bench testing was conducted to characterize the custom sensors. The research team validated fit and function when walking with Smart AFO on level ground while real-time sensor data were recorded in the App. A focus group was conducted with local clinicians to gather feedback on the Smart AFO system.

RESULTS
Three prototype devices were fabricated and evaluated with a standard footplate and tibial cuff. The ankle moment sensor measured a range of 290 ± 28.3 Nm with a resolution of 0.073 ± 0.005 Nm and a mean absolute percent error full scale (MAPE %FS) of 0.163 ± 0.067. The ankle angle sensor measured a range of 33.0 ± 2.57 degrees with a resolution of 0.053 ± 0.006 degrees and a MAPE %FS of 2.38 ± 2.07. The App successfully streamed sensor data from Smart AFO, detected steps, and displayed a graph of the moment and angle data across percent stance of each step. Focus group participants were enthusiastic about the concept of "being able to have data quickly and get suggestions to then convert to the definitive [orthosis]."

DISCUSSION AND CONCLUSION
The Smart AFO system demonstrated the ability to measure gait data from an instrumented orthosis and stream these data to an App in preparation for AFO user testing. With implementation of a tuning algorithm in ongoing development, the system will use the quantitative gait data to provide orthotists with visual guidance on ankle range of motion and stiffness adjustments to achieve an optimal AFO for post-stroke individuals.

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3.2.2.c
Surrogate Lower Limb Design for Ankle-Foot Orthosis Testing

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BACKGROUND
Ankle-foot orthosis (AFO) mechanical testing has been performed with simple limb surrogates, typically with a single axis ankle joint and rigid foot and shank components [1]. Since many current AFO designs provide movements in 3D, a surrogate lower limb (SLL) that provides anatomically viable movement in all planes is needed to enable test-load and cyclic testing in a controlled manner.

AIM
Design a novel SLL that provides anatomical 3D foot movement, based on a consensus of passive RoM in the literature. The design should enable the SLL to be affordably manufactured and accessible to a range of end-users.

METHOD
The SLL design was inspired by the Rizzoli model [2], sectioning the lower limb into five segments (shank, hindfoot, midfoot, forefoot, toes). Ball and socket joints are used for the shank-hindfoot, hindfoot-midfoot, and midfoot-forefoot. Forefoot-toes use a hinge-type joint. 3D printed flexible thermoplastic polyurethane (TPU) snap-fit connectors connect the 3D printed nylon foot blocks. A threaded ball stud connects the shank shaft and hindfoot. This shank shaft is surrounded by a 3D printed polylactic acid (PLA) shank cover. The foot is cast in silicone rubber to emulate soft tissue, with a PLA custom mold based on an Össur prosthetic foot cover model.

RESULTS
The SLL was successfully designed for easy fabrication using readily available techniques, materials, and components (figure 1). Only the metal shaft requires a machine shop. 3D printed components used an affordable 3D printer (Artillery Sidewinder X1), and readily available nylon, PLA, and TPU. Nylon 230 is chosen for its non-abrasiveness and low melting temperature, allowing more 3D printers to use the filament. Ninja Tek Cheetah™ is chosen for its low cost and high printability compared to other TPU filaments. Mold star 30™ silicone rubber is chosen for its low viscosity and not requiring degassing or controlled heat during curing. Low-cost PLA is used for the mold and shank cover since these larger prints require no strength. SLL foot rotation angles were found to be within standard deviation of mean foot passive ranges found in the literature.

Figure 1. SLL assembly

DISCUSSION AND CONCLUSION
SLL fabrication is simple and requires minimal outside assistance and minimal machining. The 3D printed construction shows high versatility using high infill settings for nylon and TPU and low infill settings for PLA. All blocks can be printed within hours, and casting requires 6 hours to cure. Initial testing showed small dimensional inaccuracies due to small warping and shrinking. However, proper dimensioning and settings allowed better fits, mitigating these issues. Even with these inaccuracies, results were within human variability.

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3.2.2.d

Assessment of Speed, Accuracy and Reliability of Five 3D Scanners to Capture Foot and Lower Leg Morphology for AFO Fabrication

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BACKGROUND

Taking plaster cast impressions of the foot and lower leg to produce customised ankle-foot orthoses (AFOs) is time consuming, requires consumables and purpose-built facilities. 3D scanning technology provides a digital solution to acquiring foot and ankle morphology. However, there are few studies that investigated various 3D scanners to capture ankle and foot morphology [1] with no studies comparing the reliability and accuracy of multiple 3D scanners for scanning the ankle and foot.

AIM

The aim of this study was to evaluate the speed, accuracy and reliability of five commercially available 3D scanners to capture foot and lower limb morphology necessary to fabricate AFOs.

METHOD

Five handheld 3D scanners (iPhone appTrnio, Structure Sensor, Structure SDK, Sense Scanner, Artec Eva) were included. First, the accuracy of each scanner was assessed by scanning an object of known dimensions. Second, reliability of clinical measurement parameters with each scanner were assessed twice on the same day in three healthy participants. Absolute agreement of 5% was set for acceptable repeatability. Finally, the speed, accuracy and reliability of each scanner was assessed in 10 healthy participants and compared with clinical measures (ground truth). The reliability of each scanner was tested on the ten participants using ICC (3,1), accuracy was analysed using absolute agreement and scanning time recorded.

RESULTS

The accuracy of each of the six 3D scanners was assessed by scanning an object of known dimension and four scanners were in agreement (1.9%-2.9%). For the initial three participants, there was a high mean agreement between morning and afternoon clinical measurements (0.85%) and morning and afternoon scans (3.3%-8.7%; Figure 1). Repeated digital measurements of 3D scans were in the range of agreement (1.4%-2.6%). When comparing the 3D scanners with clinical measurements, not all scanners met the target of agreement.

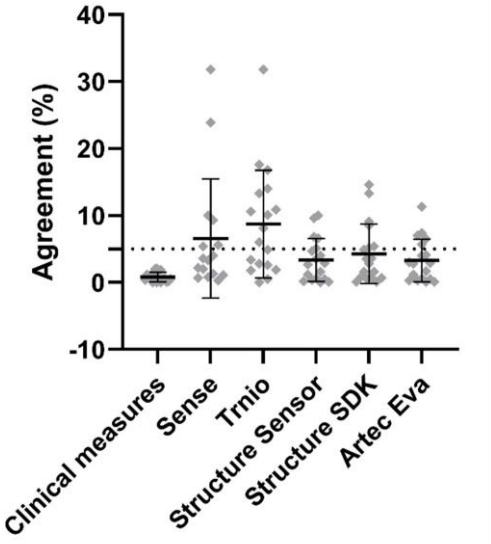

Figure 1. Mean agreement between repeated 3D scanners and clinical measurements over six measures (forefoot, rearfoot, malleolus, arch height, midcuff, foot length) from three healthy participants' foot and ankle. Error bars, SD; dotted line, 5% agreement.

DISCUSSION AND CONCLUSION

The main finding of this study was that some 3D scanners were higher in agreement when compared with repeated measures than others. Analysis of all 10 participants' results will present a deeper understanding on the speed, accuracy and reliability of these available 3D scanners. Although this study was limited to healthy volunteers, future investigations will include participants that are prescribed AFOs.

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3.2.2.e
Strength of Recycled Polypropylene and its Use in Orthotic and Prosthetic Care

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BACKGROUND
Homopolymer Polypropylene (PPH) is a commonly used thermoplastic within the Orthotics and Prosthetics (O&P) industry worldwide. PPH is versatile: durable, lightweight, good strength-to-weight ratio, and chemical resistant. Although a widely used thermoplastic, PPH is one of the least to be recycled (under one percent). Given that PPH is a thermoformed plastic, it has a high potential to maintain its original strength properties when recycled.

AIM
Measure and compare the tensile properties of recycled Homopolymer Polypropylene.

METHOD
PPH was recycled and injection molded to form specimens meeting the American Society for Testing and Materials (ASTM) D638 Type I standard. The new sheet of PPH was granulated, heat-injected into a mold, and cooled. Specimens had to be free of air bubbles and meet the measurements. Granules were injection molded until five qualifiable specimens were achieved. The remaining granules were heat-injected and kept clean. Once all material was heat-injected, it was granulated for another heat-injection cycle (five recycles with the first granulation being the first recycle). Tensile testing was accomplished, and data were analysed using linear regression by SPSS software.

RESULTS
When accounting for the duration of the mold spent in the oven and the duration of the granules spent in the injection barrel, recycle groups did not significantly predict tensile strength. Recycle Group, duration of mold in the oven, and duration of granules in the injection barrel together explain 74.3% of the variability in tensile strength (r^2=0.743). For every 1 minute in the oven, the tensile strength increased by 29.721 PSI, on average (p=0.019). For every 1 minute in the barrel, the tensile strength increased by 21.798 PSI, on average (p=0.016).

DISCUSSION AND CONCLUSION
Recycled Homopolymer Polypropylene plastic, we suggest, may be a viable low-cost material for the Orthotics and Prosthetics field. By recycling multiple times, there are tremendous cost savings while maintaining tensile strength. This has unlimited potential worldwide in rehabilitation and overall healthcare settings. The environment will benefit from a decrease in hazardous polypropylene plastic waste in landfills. Further research in 1) strength comparison to original material before granulation and 2) injection processing is warranted.

Free Paper Session
Education

3.2.3.a
Pacific Wayfinders: A Mentoring Programme for Pacific Island Rehabilitation and Assistive Technology Personnel

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BACKGROUND
There is a growing rehabilitation workforce across the Pacific region, however CPD, leadership and mentoring opportunities are lacking. In Motivation Australia's 2020 Continuous Professional Development and Online Learning survey, 34% of health workers surveyed from Pacific Island Countries (PICs) indicated they learn best from one-on-one mentoring. 98% (49/50) were interested in group mentoring with other health professionals in the region. The Pacific Wayfinders mentoring programme responds to the need for continuous professional development opportunities for rehabilitation workers in PICs.

AIM
The Pacific Wayfinders mentoring programme aims to develop the professional and personal skills of rehabilitation and health workers and health service managers working in PICs, Australia and New Zealand, by providing them with access to a formal mentoring programme.

METHOD
The programme began in November 2020, recruiting health workers and leaders from PICs, New Zealand and Australia through existing networks, social media, recruitment platforms, manager referrals and word of mouth. Motivation Australia provided supporting resources throughout the programme including virtual induction sessions. The resources provided background information and a framework for participants to facilitate participation and positive growth of the mentoring relationship. Mentees and mentors met at least once per month over the eight-month period and communicated at least weekly via text communication (including email, messaging platforms, *Facebook* or other). The programme will be evaluated through qualitative feedback and quantitative analysis of the achievement of goals.

RESULTS
15 one-on-one mentoring relationships were formed at the start of the programme. The programme will conclude in June 2021. Therefore, final results are not yet available as of March 2021. However, initial qualitative feedback has been positive as is evident in this quote from one of the participants. "Before trying to summarise into SMART Goals I wondered how we would bring all these ideas and dreams into measurable goals, but now in hindsight from today's session I can see that it all links up to make a bigger picture which helps us focus in on development as both mentor and mentee." Further, as a direct result of the programme, one of the participants has identified leadership opportunities and been accepted into a human rights course.

DISCUSSION AND CONCLUSION
Health and rehabilitation personnel in Pacific Island Countries are relatively isolated from professional networks. The Pacific Wayfinders programme has provided a platform for people working in rehabilitation and assistive technology in the Pacific region to connect with professionals outside of their own countries. The learning has been mutually beneficial for both mentors and mentees. Following the relationship and outcomes over a longer period will be an important next step to determine the longer-term impact of the programme.

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3.2.3.b

Prosthetics and Orthotics Students' Perceptions of Online Courses During the COVID-19 Pandemic in Japan

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BACKGROUND

The outbreak of the novel coronavirus (COVID-19) spread rapidly from Wuhan to other regions in China, then the global region. The global population has been switching from traditional to digital lifestyles. This rapid change of lifestyle has consequently affected various disciplines including medical staff and trainees [1]. Prosthetics and Orthotics (P&O) trainees require theoretical and practical classes on campus and clinical placements in rehabilitation centres and industries as well.

AIM

This cross-sectional survey investigates the effects of COVID-19 on the prosthetics and orthotics training programme from students' perceptions.

METHOD

This cross-sectional online survey collected data from P&O students across Japan. Participation was voluntary and students can easily terminate the survey any time they like. This study has been approved by Niigata University of Health and Welfare research ethic committee (approval No.18527-201112). All heads of prosthetics and orthotics training programs in Universities and Colleges in Japan were contacted via email. The purpose of the research was clearly explained in the mail with the questionnaire link to be distributed among all students. The survey participation consent was clearly stated at the beginning of the online-based survey. The data were collected from the middle of December 2020 to the end of January 2021.

RESULTS

One hundred and sixty-six students (107 males and 59 females) responded to the survey. The respondent's grades were as follows: Freshman; 22.3% (n=37), Sophomore; 33.7% (n=56), Junior; 27.1% (n=45) and Senior; 16.9% (n=28). Forty-seven per cent (n=78) reported that their clinical placements have been cancelled due to COVID-19. Only 15.1% (n=25) have done their clinical placements during the pandemic. Regarding career preparation, 16.3% (n=27) had face-to-face interviews, 10.2% (n=17) have reported being interviewed online and 4.2% (n=7) job appointments have been postponed in P&O rehabilitation services facilities. Most students expressed their wishes to return to a normal lifestyle and start a face-to-face class in the near future. Furthermore, those who would likely to spend an extra year in university due to COVID-19 represented 8.4% (n=14).

DISCUSSION AND CONCLUSION

Learning online might be difficult for some disadvantaged students. The event of the COVID-19 pandemic has proved the necessity to renew the traditional teaching and learning model in colleges worldwide. Most students have been affected in terms of clinical placements. Therefore, promoting telehealth in the existing rehabilitation facilities and P&O industries to provide services might be an alternative method to address students' clinical placements in similar life condition events.

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ACKNOWLEDGEMENTS: We are thankful to all students who completed the survey and to Prof. Kazuhiro Sakai for revising the survey.

3.2.3.c
Challenges Faced by Prosthetic and Orthotic Students on Clinical Placement

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BACKGROUND
Clinical placements are an essential component of the Prosthetics and Orthotics (P&O) undergraduate course at the University of Strathclyde. Students undertake two, four-month placements in the UK, Ireland or overseas. Placements present many challenges [1,2]. There is literature investigating challenges faced by other AHP students, but little is known about the unique challenges that P&O students face on placement.

AIM
To investigate the challenges experienced by P&O students on clinical placement, and to create a guide using this information to support students on placement in the future.

METHOD
Nine participants took part in a focus group. Participants were final year P&O students who completed their placement in 2019 in the UK or Ireland. A focus group was held to better understand the students' thoughts and feelings around placement [2]. Participants were asked questions about the placement assessment and structure, wellbeing, accommodation and travel, finance and support from supervisors. The discussion was recorded, transcribed and pseudo-anonymised. Analysis was carried out using Nvivo software. Analysis was approached using Braun and Clarke's [3] six phase method, for thematic analysis of qualitative data.

RESULTS
Five themes relating to challenges experienced by students on placement emerged from the focus group; challenges related to: the placement centre and staff, finance and accommodation, relationships with supervisors and placement staff, wellbeing, and advice for future students. Theme 1 was broken down into three subthemes; challenges related to; (A) the size/patient numbers in a centre, (B) the structure and assessment of the placement and (C) the supervisor's teaching methods. Although several challenges of clinical placements were discussed, many positive aspects of placements also came to light, such as characteristics of a good placement supervisor and aspects of a successful placement. Many students gave advice for future students on how to navigate their way through placement.

DISCUSSION AND CONCLUSION
This project identified several challenges that P&O students face on placement. Several challenges were similar to those in other AHP literature, however P&O students face some unique challenges. Universities and placement centres should ensure students are well supported in every area of their education and understand external issues which can impact on student learning. A guide was created using participant experience and advice to aid future students through their placement.

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ACKNOWLEDGEMENTS: Thank you to the participants of this study, as well as Cailin McKie for facilitating in the focus group.

3.2.3.d
A Systematic Review of Prosthetics and Orthotics Education Research

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BACKGROUND
Global education in prosthetics and orthotics (P&O) continues to evolve. In the last five years, the International Society for Prosthetics and Orthotics and the World Health Organization have published standards for both education [1] and service delivery [2] in P&O. Additionally, the ISPO Global Educators Meeting [3] serves as a valuable opportunity to cultivate collaborations and development of P&O curriculum and pedagogy. However, despite these developments in P&O education, the current state-of-the-science in P&O education is largely unknown.

AIM
This systematic review was conducted to describe the current state-of-the-science in peer-reviewed P&O education research [4]. We sought to evaluate and synthesize published literature in P&O education and identify priorities for future research.

METHOD
A systematic search of the literature was conducted in August, 2019 using three databases: PubMed, CINAHL, and Web of Science. Additionally, references of key P&O documents and online conference proceedings were hand searched. A priori inclusion/exclusion criteria were established. Articles had to be (1) written or translated into English, (2) published in peer-reviewed journals, and (3) examine formal education of prosthetists and/or orthotists. Two researchers independently assessed methodological quality of included studies using the Critical Appraisal Skills Programme qualitative checklist, National Institutes for Health Quality Assessment Tool for Observational Cohort and Cross-sectional Studies and/or specific Delphi method criteria.

RESULTS
Twenty-five articles from 23 independent studies were included in the final review. Four studies were mixed methods, 12 were quantitative, eight were qualitative, and one used a purely qualitative survey. Researcher-developed surveys, Delphi methods and semi-structured interviews were used in most studies. Studies were conducted across the world and included multi-country collaborations. Six articles were determined to be high quality, six were moderate and the remaining thirteen studies were of low quality. Articles explored teaching/learning methods, aspects of content/curriculum, program-level topics, or provided descriptions of country or regional education. Most studies used students or instructors as the source of data. Reported learner outcomes were primarily assessed at the level of reaction, attitude/perceptions or knowledge/skills. No studies assessed organizational practice or patient benefit as the outcome of interest.

DISCUSSION AND CONCLUSION
A small body of evidence exists in P&O education, spanning geographic locations, topics and methodologies. Consensus statements were not possible due to study heterogeneity, however, opportunities to improve P&O education research were identified. For example, increased collaboration among educators and researchers could enhance the quality of published literature. Additionally, P&O evidence-based education would benefit from dedicated research funding, prioritization of faculty development and a culture shift toward peer-reviewed publication to best inform the education of future clinicians.

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3.2.3.e

Pandemic Pedagogies Advancing Prosthetic and Orthotic Education at George Brown College

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BACKGROUND

The pandemic negatively impacted experiential learning and field placements. Since then programs have re-emerged with innovations that have resulted in improvements in teacher-student ratios, more diverse learning environments, flipped/asynchronous and distance based learning [1]. Done properly, a virtual classroom gives every student a front row seat, recorded sessions and an inclusive and interactive community [2].

AIM

To share best practices and lessons learned in moving to online / blended format, that while borne out of necessity, enhanced pedagogical strategies henceforth. These changes will allow for the education of more students, with less resources, and varied learning modalities.

METHOD

The use of surveys to validate the aim of the study will be employed. Students from various cohorts and faculty, with pre and post pandemic experiences have and will be surveyed. Ways in which resources were deployed to allow for a/synchronous online lectures and demonstrations will be reported.

RESULTS

Survey results highlight student and faculty experiences, areas of success, and opportunities for future growth and development. Additionally, examples will be given of ways in which curriculum was modified to minimize the time and number of students on-site while still maintaining high quality experiential learning opportunities.

DISCUSSION AND CONCLUSION

Survey results demonstrate and support the ways in which curriculum was modified to maximize the effectiveness of on-site applied learning and online content. Moving lectures, theory, evaluations, and research presentations to an online format allowed for pure applied learning to take place on-site. Flipped content of applied techniques had a positive impact on the learner's experience allowing for more efficient and higher-level applied learning to occur when students were on-site.

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ACKNOWLEDGEMENTS: George Brown College.

Basic Instructional Course
Prosthetics: Lower Limb

3.3.1
Sustainable, Affordable and Functional: The AERO Prosthetic Liner Course

Gary Guerra, Kazuhiko Sasaki, Yusuke Miyata, Kensuke Sugawara

Sirindhorn School of Prosthetics and Orthotics, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand

Abstract
Sustainable development in resource limited settings is challenging. There is a need to develop technologies that support local sustainable development goals and that offer locals a means to develop "in-house" clinical solutions. The trans-tibial prosthesis has evolved to offer optimal weight bearing and enhanced suspension. The Affordable Ethyl-Vinyl-Acetate Roll-On liner (AERO) was designed to be locally produced roll-on liner for fabricating total surface bearing prostheses in resource limited environments (RLE). This course will introduce the rationale behind the AERO development and techniques for retrofit as well as custom fabrication. Through demonstration, attendees will learn how to create liners in their own facilities with local materials. Time for questions and answers will be provided.

Statement of the learning objectives
AERO Liner Course

- Attendees will have an opportunity to rethink what liner provision in resource limited settings can be
- Fabrication for both retrofitting and custom fitting the AERO liner will be offered

Advanced Instructional Course
Orthotics: Lower Limb

3.3.2
Evidence-Based Practice of Gait Training in Early Post Stroke Using Lower Limb Orthoses

Hiroshi Hashimoto[1], Souji Tanaka[2], Sumiko Yamamoto[3]

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Abstract
Gait training in early post stroke is a re-learning process. It is important for physiotherapists to control the alignment of the limbs and to improve muscle activity during gait using orthoses and interventions. As several researches have shown, stiffness of the AFO affects the gait in post-stroke and evidence-based practice based on these findings is necessary.

We hypothesize that gait training using AFOs with adequate levels of stiffness in plantar flexion improves the early stance of the paretic limbs. This may also be beneficial in achieving gait rehabilitation of individuals with stroke.

Based on this hypothesis, we have made a tentative flowchart to show the decision-making process of the selection of AFOs with adequate functionalities to individual users and appropriate interventions. It is based on practical data: the information of observational gait analysis mainly focusing on shank inclination in paretic stance, physical functions of each user, and muscle activities measured with portable EMG sensors during gait.

In this course, case reports of individuals with stroke using various kinds of orthoses are shown including gait video and EMG data to demonstrate:

How to evaluate the gait to adjust the AFO functions and select appropriate interventions
How to evaluate muscle activity
How to record and share the process of gait training
How the gait is improved after this procedure

Statement of the learning objectives
To show how the actual gait of individuals with stroke changes before and after intervention using orthoses and provide information on how to increase the effect of gait training in early post stroke using orthoses.

Free Paper Session
Prosthetics: Lower Limb 2

3.4.1.a

Manufacture of Bilateral Transtibial Prostheses for a Child with Congenital Quadrilateral Limb Deficiencies Using Quasi-Extended Residual Limbs: a Case Study

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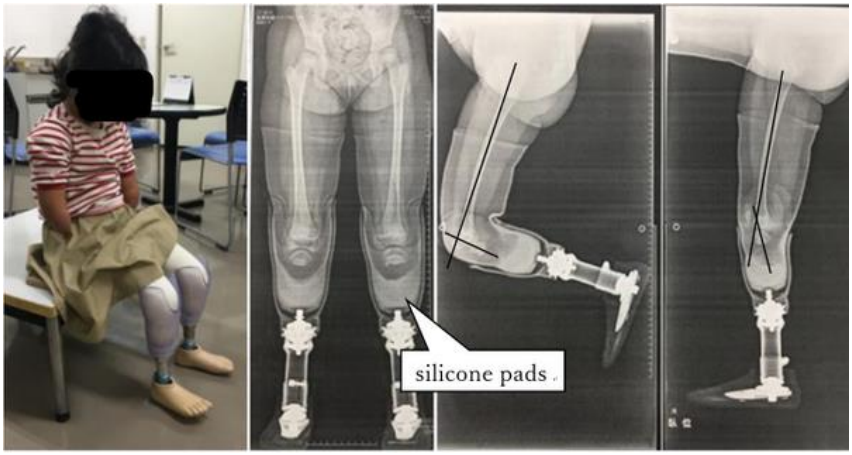
[1]Kawamura Gishi Co. Ltd, Daitō, Japan. [2]Osaka Rehabilitation Hospital for Children, Osaka, Japan

BACKGROUND
Bent-Knee Prostheses are prescribed for persons with extremely short transtibial residual limbs instead of transtibial prostheses for increased stability. However, their use restricts the range of motion of the biological knee joints. Of special consideration, Japanese children are required to flex the knee joints more than adults while sitting on the floor or crouching.

AIM
The production of transtibial prostheses with quasi-extended residual limbs in order to take advantage of the natural range of motion of knee joints for a child with congenital quadrilateral limb deficiencies.

METHOD
The patient was a six-year-old female with congenital quadrilateral limb deficiencies. She had used bent-knee prostheses. The range of motion of her knee joints were 0-90°and the length of her residual limbs were 30mm in full extension and 15mm in 90°flexion. Transtibial prostheses with total surface bearing sockets and higher bilateral walls were manufactured. To extend the length of the residual limbs, QUICK-SIL ™ silicone resin was injected in the bottom of Iceross ® silicone liners at the depth of 35 mm to elongate the stump lengths artificially. The lengths of the prostheses were 253mm from MPT to the floor.

RESULTS
The stump length including the liner was 80 mm. X-ray photography showed that the silicone pad fitted well to the stump in the sockets, and knee joints were also flexed more. The patient could also don and doff the prostheses by herself. There were no remarkable instabilities between the residual limbs and silicone pads, silicone pads and liners, and liners and sockets. She could stand in them with good balance. Slight flexion of both knee joints was observed during walking. She could also sit in chairs at 90°flexed knee position and sit on the floor. Compared to normal bent-knee prostheses, the appearance was considerably improved and she was quite satisfied with them.



DISCUSSION AND CONCLUSION
These transtibial prostheses using silicone pads to elongate the residual limbs had the same function as common transtibial prostheses. The silicone pads appeared to contribute to stability during both stance and walking. The improved range in knee joints also improved both her level of activity and quality of daily life. This demonstrated that this method may be useful for persons with extremely short transtibial residual limbs.

3.4.1.b

A Randomized, Cross-over Predictive Validity Study of a Novel Test-Drive Strategy for Prosthetic Foot Prescription

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BACKGROUND

There is limited objective evidence to guide clinicians during prosthetic foot prescription, and people with amputations generally have scant opportunity to provide experiential input during foot selection [1,2].

AIM

We aimed to determine whether evaluation after a trial of candidate feet could predict longer-term foot preference after a two-week period of use in the community, and secondarily whether performance-based and self-report outcomes differed between most- and least-preferred prosthetic feet.

METHOD

This was a multisite, randomized, participant-blinded, cross-over study. Participants trialed three different types of commercial prosthetic feet and three corresponding emulated feet using a novel robotic prosthetic foot emulator (PFE) [3]. The PFE can be programmed to mimic the mechanical behaviour of different feet, and is capable of rapidly switching between foot profiles using software. Participants walked on a level and inclined treadmill, and either walked on a stairmill or completed a standing test in each foot. After the laboratory visit, participants were fit with each of the commercial feet for two-week use trial (i.e., 2 weeks in each foot). All foot conditions were randomized and participant-blinded.

RESULTS

Foot preference scores following two weeks of use were significantly correlated with foot preference scores reported after a brief in-lab trial using either the commercial or emulated feet ($p \leq 0.036$) (Figure 1).

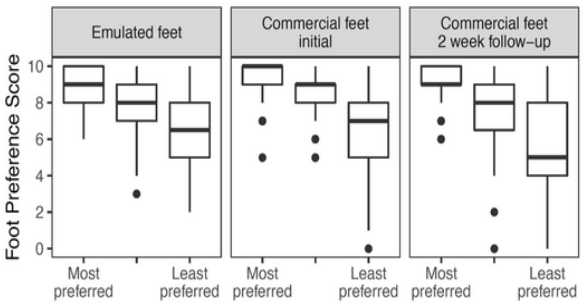

Figure 1. Box plots of foot preference scores across most to least preferred feet for each testing session showing median, upper and lower quartiles, and outliers.

At least 73% and 55% of in-lab preference scores using the PFE, and at least 73% and 57% using the commercial feet, were within 2 and 1 points respectively of the corresponding scores obtained after two weeks of use. Participants' scores on the BBS ($p=0.009$), NBWT ($p=0.026$), PLUS-M ($p<0.001$), ABC Scale ($p<0.001$), and TAPES-Satisfaction scale ($p<0.001$) were significantly higher in the most-preferred foot than in the least-preferred foot after the two-week period of use. Linear mixed-effects regression was used to assess associations between participants' initial foot preference score. A Wilcoxon signed ranks test was used to compare self-report and performance-based outcomes in the most-preferred versus the least-preferred foot.

DISCUSSION AND CONCLUSION

The results of this study suggest that 1) A brief in-lab or in-clinic trial of prosthetic feet can predict prosthetic foot preference after a longer-term period of home and community use, and 2) Use of preferred feet can lead to improved functional and patient-reported outcomes. Since patient satisfaction is a vital aspect of success with foot prescription [4], this research suggests that a patient-cantered, test-drive strategy for prosthetic foot prescription could enhance both patient satisfaction and clinical outcomes.

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ACKNOWLEDGEMENTS: The authors would like to thank Jane Shofer, MS, for performing the statistical analysis for this study.

3.4.1.c

Exploring Decisional Needs of Prosthetists and Patients with Lower Limb Amputation for Prosthesis Design: A Qualitative Shared Decision-making Study

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BACKGROUND

The abundance of prosthesis design options for patients with lower limb amputation (LLA) can make prosthetic treatment decisions complex [1]. Additionally, patient expectations after LLA can influence long term outcomes, creating a mismatch between expectations and reality, which may contribute to dissatisfaction and reduce prosthesis use [2]. Shared decision-making offers the potential to help patients and prosthetists work together to choose the best possible options that align with a patient's needs and values [3].

AIM

To qualitatively explore the decisional needs of prosthetists and patients with new LLA when making prosthesis design decisions and to inform the design of a shared decision-making tool.

METHOD

This study was approved by the Colorado Multiple Institution Review Board. Prosthetists and patients using their first prosthesis were purposively recruited for interviews from the USA via email inquiry through clinic partners, listservs, and support groups. Recruitment continued until thematic saturation was achieved [4]. Semi-structured interviews (phone or online video conference) were conducted, audio recorded, and transcribed by a trained researcher with a total of 17 patients. Additionally, six separate focus groups were conducted with a total of 38 prosthetists. Transcripts were coded and analysed using a directed content analysis approach, guided by Elwyn's Shared Decision Making Model for Clinical Practice [3] and the Ottawa Decision Support Framework [5].

RESULTS

Three preliminary themes around decisional needs were identified: therapeutic alliance, identifying values, and exposure to options. Patients and prosthetists both described the importance of developing an alliance and trust, which was perceived as essential for identifying communication preferences when presenting information. Although most patients desired awareness of prosthesis design options and anticipated decision points, both patients and prosthetists recognized the challenge of introducing information without overwhelming patients early in the prosthesis design process. Patients and prosthetists both emphasized a need for early guidance and support in identifying individual patient values related to prosthesis design decisions. Finally, both prosthetists and patients described how a patient's exposure to or experience using various prosthesis components was key for achieving informed preferences (via peer support, show and tell, demonstration, or trials using prosthetic options).

DISCUSSION AND CONCLUSION

Patients and prosthetists described key needs for supporting shared decision-making for prosthetic design decisions early after LLA. Decision support for prosthesis design should incorporate individual values-focused communication. The themes identified in this work can inform shared decision-making tools to promote collaborative discussion between prosthetists and patients with LLA on prosthesis design and the anticipated decision points in prosthetic care.

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3.4.1.d

Importance of Heel Height Adjustability in Prosthetic Feet for Persons with a Leg Amputation: Results of an Online Survey

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BACKGROUND

Only few prosthetic feet offer adjustable heel height to accommodate different shoes. This problem has rarely been addressed in the literature and the significance to users is still unclear [1-3]. A questionnaire was developed using a two-stage Delphi-process to determine clinically relevant aspects in prosthetics. Users later rated these aspects in addition to heel height adjustability.

AIM

The aim was to estimate the importance of heel adjustability in prosthetic feet for individuals with a lower limb amputation. For that reason, a questionnaire was developed by means of a Delphi process.

METHOD

We asked 93 experts (prosthetists, physiotherapists, physicians, etc.) what their ideal prosthesis of choice would be like and which technical features would determine it. Subsequently, the answers were categorized and coded by content analysis. The categories were arranged according to the frequency of the assigned answers. The first ten, most frequently mentioned categories and heel height adjustability were included in the questionnaire addressed to users. An online version of the user questionnaire was created [4].

RESULTS

The questionnaire was online for 100 days and was advertised via social media, support groups and journals. 189 people responded (83♀, 106♂, 44% trans-tibial, 36% trans-femoral, 44% traumatic). Item "Well-fitting and comfortable socket" was rated highest with an average of 9.6 of 10 (SD±1.3). Heel height adjustability was rated with 8.7 of 10 (SD±2.2). Participants were asked to rank their 10 most important properties, with 63% of women choosing “heel height adjustability” as top 10 item and 47% of men. 31% selected "Well-fitting and comfortable socket" as #1 and just 1.6% heel height adjustability.

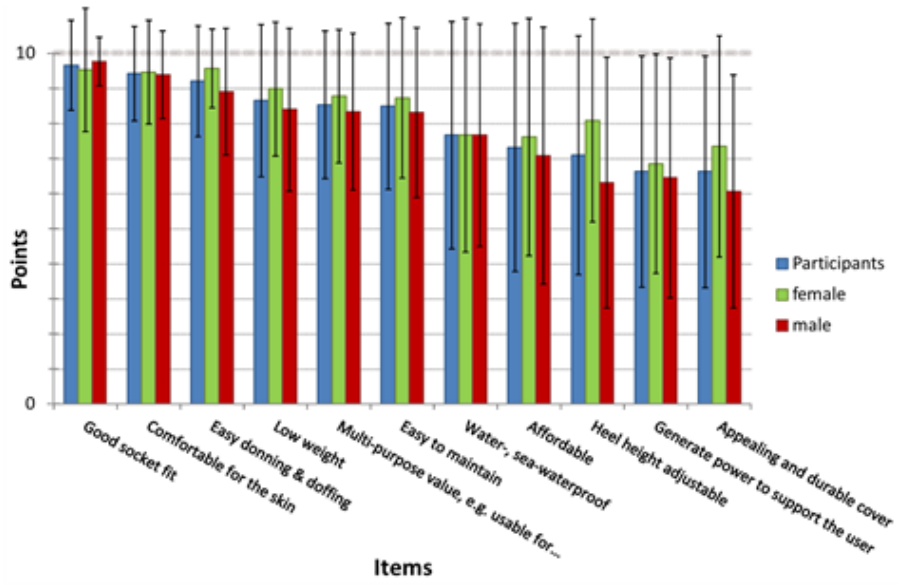

Figure: Rating of the eleven items on the 10 point scale with gender specific ratings.

DISCUSSION AND CONCLUSION

Heel height adjustability was ranked 9th out of all 11items.Thus, there is a need for shoe heel adjustment for prosthetic feet, but other, e.g. socket related were characteristics rated as more important. Women rated heel adjustment higher than men.

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ACKNOWLEDGEMENTS: We acknowledge efforts of participants, financial support of Össur-hf and BMAB e.V., Anpfiff ins Leben, Barriere-FREI, Orthopädie-Technik for advertising survey.

3.4.1.e
Evaluation of Amputee Rehabilitation Services in Gaza Governorates: Mixed Method Approach

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[1]International Committee of Red Cross (ICRC), Physical Rehabilitation Program, Gaza, Palestine. [2]Al-Quds University, School of Public Health, Gaza, Palestine

BACKGROUND
People with amputations require integrated rehabilitation services. Within the context of the Gaza Governorate (GG), no studies have been conducted to evaluate the provided rehabilitation services to people with amputations.

AIM
This study aims to evaluate and understand the available rehabilitation services to people with amputations in the Gaza Governorate in order to propose recommendations and interventions, thus, well may improve the overall well-being of people with amputations.

METHOD
This study utilized a mixed-method approach; the quantitative study is cross-sectional that involved collecting demographic, socio-economic, clinical, and quality of life data from randomly selected 370 people with amputations through a face-to- face questionnaire. The qualitative data were collected through conducting eight in-depth interviews with key informants and three focus group discussions with healthcare service providers.

RESULTS
In the GG, the main cause of amputations is conflict-related and the second major cause is the lower-limb amputations due to uncontrolled Diabetes Mellitus. All the study participants (370 amputees) received medical care during their hospitalization, 45.7% received physiotherapy and 24.1% received psychological support services during the same period.

Moreover, the study found that 63.1% of the participants have an average monthly income under the poverty line. The quality of life for people with amputations is generally good. 45.3% of clients have reported a good quality of life compared to 19% who did report poor quality of life and 1.6% who reported a very low quality of life. Additionally, from the study participants point view, the society was not fair enough to them as they feel somehow discriminated and socially excluded.

DISCUSSION AND CONCLUSION
People with amputations are not receiving comprehensive services, thus services provided need to be tailored to meet the need of people with amputations, including health and education services as well as social inclusion activities.

Symposium
Orthotics: Spinal

3.4.2
Advanced Orthotic Systems for Management of Adolescent Idiopathic Scoliosis

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Abstract
Scoliosis is a three-dimensional spinal deformity usually with lateral curvature and vertebral rotation of the spine. Most cases are with unknown cause and found in adolescence, therefore, it is termed as adolescent idiopathic scoliosis (AIS). For severe cases, surgeries will be considered while for moderate AIS, conventional orthotic treatment method is generally applied via rigid spinal orthoses to patients during their puberty to mechanically support the spine and prevent further deterioration. The outcome of orthotic treatment for AIS is considered being associated with the immediate in-orthosis correction and the patient's compliance. The more often the patients wear their spinal orthoses to the prescribed tightness as well as to the prescribed length of time each day, the better the treatment outcome expected. However, the current orthotic techniques seem non-scientific although there is some evidence to demonstrate the spinal orthosis being effective. There is lack of technical information such as: "How tight should patients wear the orthoses? How long should they wear the orthoses? How good their compliance really is at home and at school? Whether all these factors are really important and necessary and related to the clinical efficacy?" This symposium will share clinical experiences and scientific evidence in order to better understand the science behind the phenomenon that orthoses appear effective and go further for evidence-based practice.

Statement of the learning objectives
The involved speakers are the world-leading pioneers in the research of orthotic management of AIS and delegates will be shared these advanced techniques during the symposium.

Free Paper Session
Prosthetics: Lower Limb – Osseointegration

3.5.1.a
Osseointegration Implant Failure and Surgical Revision in Persons with Bone-Anchored Prosthesis after Transfemoral Amputation

Jamal Mohamed, David Reetz, Henk van de Meent, Hendrik Schreuder, Jan Paul Frölke, Ruud Leijendekkers

Radboud University Medical Center, Nijmegen, Netherlands

BACKGROUND
Stem breakage due to metal fatigue is a rare but well-known cause for failure of orthopaedic implants. This may also affect the components of the osseointegration implant (OI) system for individuals with transfemoral amputation with subsequent need for revision. Identification of risk factors is important to prevent implant failures.

AIM
To identify potential patient, implant, and event characteristics associated with OI failure and to describe surgical revision strategy and technique that was subsequently performed.

METHOD
This study is a single-centre retrospective cohort study with a minimum of 5-years follow-up. All consecutive participants with transfemoral or through-knee amputation who underwent OI surgery between May 2009 and July 2015 were eligible for inclusion.

The revision of a failed intramedullary stem due to breakage consisted of three stages including removal of the broken stem in two separate procedures. Finally, after wound healing and bone recovery the new intramedullary stem was installed.

In case of (a)septic loosening of the intramedullary stem, the stem was removed in two separate stages. Bone cultures were taken during these procedures to assure sterile conditions for instalment of a new intramedullary stem.

RESULTS
In total, 58 (59 implants) of 60 eligible patients were included of which 7 patients with an intramedullary stem failure (6 breakages and 1 septic loosening). The cumulative survival rate was 77% after 9.0-years. Patients with a stem failure had a statistically significant smaller intramedullary stem diameter and more infectious events compared to the non-failure group. Thirteen of the 58 individuals experienced 14 DCA failures of which 10 weak-point breakages and 4 distal taper breakages. No potential risk factor was found.

DISCUSSION AND CONCLUSION
Small stem diameter and number of infectious events are possible risk factors for OI system failure in cast CoCrMb OIs. It is advisable to avoid small stem diameter. All seven patients underwent successful revision with a larger diameter titanium alloy OI and all DCA failures were successfully solved, mostly in an outpatient setting.

3.5.1.b

Radiological Signs of Osteoarthritis of Hip and Knee in Lower Limb Amputees that Apply for Bone Anchored Prostheses

Jamal Mohamed, Andrew Wong, David Reetz, Robin Atallah, Henk van de Meent, Jan Paul Frölke, Ruud Leijendekkers

Radboud University Medical Center, Nijmegen, Netherlands

BACKGROUND
In the pre-surgical screening of amputees applying for a Bone-Anchored Prosthesis (BAP) we have seen that quite a few subjects have shown radiological signs of probably disuse osteoarthritis (OA) of the ipsilateral joint immediately proximal to the amputation level. Since with BAP the axial loading of these joints is restored, it is important to know the clinical consequence of the radiological signs of OA and potential progression in time.

AIM
To determine the pre-surgical incidence of hip or knee OA in persons with a lower extremity amputation and to investigate the course of OA after implantation of a BAP.

METHOD
In a single-centre cross-sectional study, all subjects who underwent osseointegration implant (OI) surgery between May 2009 and November 2019 were included. Two independent raters (JM, AW) used the Kellgren-Lawrence (KL) classification to grade the level of OA of the hip or knee of the residual limb on standard radiographs taken before surgery and at 1, 2, and 5-year follow-up. According to the classification grade 2 or higher was defined as OA. Cohens Kappa was used to measure the inter-rater reliability.

RESULTS
Two hundred and twenty-eight subjects were included of which 168 (74%) were male. The mean time between amputation and OI surgery was 14.5-years. One hundred and twenty-six (55%) and 147 (67%) subjects had radiological signs of OA at respectively pre- and in average 3.1-years post-OI surgery. In 177 transfemoral amputees 101(57%) and 120 (68%) had radiological signs of hip OA respectively pre- and 3.7-years post-OI surgery. In 51 transtibial amputees respectively 25 (49%) and 27 (53%) had radiological signs of knee OA at pre-, and 1.2-years post-BAP surgery. One patient underwent hip resurfacing surgery because of severe hip OA. Inter-rater Cohens Kappa was 0.56 (considered as moderate) with a percent agreement of 78%.

DISCUSSION AND CONCLUSION
In this study it is shown that radiological signs of OA are a common incidental finding in the pre-OI surgical diagnostics and in time it appears that the number of subjects with radiological signs of OA slightly increases. However, it is not known whether these radiological signs of OA have any clinical consequences. Further research is needed to evaluate the relation between radiologic signs and clinical symptoms.

3.5.1.c

Reducing Soft Tissue Complications of Bone-Anchored Prostheses in Individuals with a Transfemoral Amputation: a Comparative Consecutive Cohort Study

Robin Atallah, David Reetz, Nico Verdonschot, Marinus de Kleuver, Jan Paul Frölke, Ruud Leijendekkers

Radboud University Medical Center, Nijmegen, Netherlands

BACKGROUND
The use of a bone-anchored prosthesis (BAP) in individuals with a transfemoral amputation is a proven safe alternative for the conventional prosthetic socket. Soft tissue infections and minor complications occur frequently, possibly influenced by surgical technique and implant design

AIM
The primary aim is to evaluate the impact of alterations in treatment by reporting on soft tissue complications. The secondary aim is to provide a description of OI treatment evolution over time, working towards the goal of continuous treatment improvement.

METHOD
All consecutive patients with a transfemoral amputation treated with an osseointegration implant with two-stage surgery, between May 2009 and January 2018, were eligible for inclusion. During this period two major adaptations took place. After 2013 an adapted surgical technique was used, with additional reduction of soft tissues resulting in a more shallow stoma. In 2015 a transition occurred in implant used, initially being made of cobalt-chrome-molybdenum, followed by a titanium implant. Thus, three different groups were compared based on treatment received. Complications studied were: infection, implant failure, stoma problems, periprosthetic fracture, and death; and required treatment. We hypothesized that treatment adaptation would result in a decrease of soft tissue complications.

RESULTS
Ninety-three of 98 eligible individuals were included. One individual was lost to follow-up (group 1: n=40, 2: n=13, 3: n=39). Comparing groups, procedure-related infection incidence substantially decreased (group 1: 95%, 2: 36%, 3: 15%), with less events and treatment invasiveness. Stoma redundant tissue decreased and did not occur in group 3 (group 1: 13%, 2: 15%, 3: 0%). Aseptic loosening occurred once (group 1), no intramedullary stem breakage or death occurred. The incidence of surgery-related complications increased in the adapted surgical technique groups from 18% to 26-31%, especially consisting of surgical site infections after stage 1.

DISCUSSION AND CONCLUSION
Learning process and adaptations to surgical technique and implant design have led to a substantial improvement of 2-year follow-up outcomes, reflected by a decrease in incidence, severity, and invasiveness of required treatment of soft tissue infections, and of stoma problems. However, surgical technique adaptation resulted in an increase of manageable surgery-related complications such as surgical site infections.

3.5.1.d

Safety and Effectiveness of a New Bone Anchoring Prostheses (BADAL-Xtm): a Prospective Two-Years-Follow-Up in 90 Lower Limb Amputees

Hendrik Van de Meent

Radboud UMC, Nijmegen, Netherlands

BACKGROUND
BADAL-X^{tm} (OTN Implants BV, Netherlands) is a modular press-fit bone anchoring prostheses (BAP) for the direct skeletal attachment of artificial limbs. Despite the fact that dental BAPs are widely accepted in daily practice worldwide, people are still often reluctant to use BAPs for attachment of artificial limbs. Hence, prospective safety and effectiveness data of new devices are important. Previously we published the one-year follow-up data of this cohort [1].

AIM
To describe safety and effectiveness, in lower limb amputees treated with BADAL-X^{tm} OFI-C, OFI-Y and OTI for long-, and short-femoral, and tibia remnants, respectively.

METHOD
All consecutive individuals treated between March 2015 and June 2018 were eligible for this study. Safety was evaluated by counting adverse events retrospectively from the medical records. Infectious adverse events were graded as: grade 1, 2, 3 and, 4 for low- and high-grade soft tissue infection, bone infection, and implant loosening, respectively. Effectiveness was prospectively measured by the Prosthetic Use Score (PUS; range 0-100) and Global Score as a measure of health-related quality of life (GS; range 0-100). These effectiveness measures were extracted from the Questionnaire of persons with Trans-Femoral Amputation (Q-TFA), at baseline before surgery and at two-year follow-up.

RESULTS
Ninety amputees (mean 54±14 yrs, 26 females) including 3 bilaterals, treated with OFI-C (n=55), OFI-Y (n=16) and OTI (n=22), were included. Safety data were derived from 90 and effectiveness from 83 subjects. In year one 22 Infectious events year were recorded: Grade 1 (n=11), Grade 2 (n=10) and Grade 4 (n=1). In year two six infectious events were recorded: Grade 1(n=3), Grade 2 (n=2) and Grade 3 (n=1). Other adverse events included stoma/myogenic pain (n=20), nerve/phantom limb pain (n=12), hip-joint pain (n=3), proximal femur fracture (n=2) and transcutaneous abutment breakages (n=4). At baseline mean ±SD and median (25th to 75th PCTL) Q-TFA-PUS and -GS were 52±39, 52(7-90) and 40±19, 42(25-50) and improved significantly to respectively 85±25, 100 (90-100) and 66±20, 75 (50-75) at two-year follow-up.

DISCUSSION AND CONCLUSION
The number of infectious adverse events sharply decreased in the second year after implantation. The two years implant survival of 99% is excellent for a new transcutaneous BAP. Stoma and Myogenic pains in the residual limb affecting 22% of patients remains an issue. However, enhanced mobility and improved quality of life more than compensate.

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3.5.1.e

10 Years Follow-up of Patients Treated with an Osseointegrated Transfemoral Implant – Outcome from the OPRA Study

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BACKGROUND
Osseointegrated prostheses have become an alternative for patients with amputations. The first prospective case-control study, the OPRA-study, started in 1999 and included 51 patients (28 men/23 women, mean age 44), with transfemoral amputations and treated with the OPRA implant in Sweden. Previously reported 2- and 5-years results showed improvements in patient-reported outcomes (PROs) alongside with complications in terms of implant loosening, mechanical complications of exchangeable implant parts and deep infections [1,2].

AIM
The aim of the current study is to report the 10-year follow-up results from the OPRA study with regard to the PROs and serious adverse events.

METHOD
Patients were followed from baseline (before treatment) and at follow-ups 2, 5, 7 and 10 years after treatment. PROs were collected at each follow-up using a general (SF-36) and a specific (Q-TFA) questionnaire. In this report, serious adverse events (SAE) include implant removal, mechanical complications and deep infections, all collected prospectively during the first two years and thereafter taken from hospital records. Descriptive statistics and analysis for differences between follow-ups are reported ($p<0.05$) as well as the survival free revision-times for the SAEs. The numbers of SAEs are compared for two time-periods (0-5 years and 5-10 years).

RESULTS
During the 10-years, 12 patients were lost (n=2 out of study <2-years, n=2 died <5-years, n=8 removed implant (n=4 <5-years, n=4 >5-years). At 10-years, the survival time was 83%, 17% and 65% for the implant, mechanical complication and deep infection, respectively.

Mechanical complications constituted the most common SAEs, occurring 201 times in 36 patients (mean 3.9 per 10 person-years) and were more common during the last five years as compared to the first five years ($p<0.001$). The number of deep infections did not change between times periods.

PROs results between baseline to 5-, 7- and 10-years, respectively, showed improvements in all four Q-TFA scores (all $p<0.0001$) and in the SF-36 Physical function score (all $p<0.0001$) and the Physical Component score (all $p<0.01$).

DISCUSSION AND CONCLUSION
This is the first study reporting prospective 10-year results of osseointegrated implants in amputees. Corroborating the short- and mid-term OPRA results [1,2], the PROs show improvements also after 10-years. However, the increasing incidence of mechanical complications of components is an important observation. Further, four more implants were removed between 5-10 years. While patients clearly benefit from having a bone-anchored prosthesis, the early detection of SAEs and reducing the rate of mechanical complications are matters of utmost concern.

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Symposium
Outcome Measurements

3.5.2
COMPASS (Consensus Outcome Measures for Prosthetic and Amputation Services): Outcomes of a Global Consensus

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Abstract
ISPO International, with the support of USAID, ATScale and UNOPS has undertaken a consensus process regarding recommended outcome measures for people with lower limb absence. Outcome measures are an important way to increase the evidence for effectiveness and cost effectiveness of clinical care and to measure quality improvements. Clinicians and policy makers need to choose between a wide array of outcome measures to answer real world questions. Given the large diversity of these measures in use, their range of psychometric properties and a variety of practical factors this choice can be challenging. The diverse range of outcome measures in use can mean data isn't readily compared.

This symposium will:

- Provide an introduction to outcome measures and their psychometric properties and set out the case for outcome measure use and the need for a global convergence of outcome measures choices.
- Describe a systematic review of outcome measures with psychometric properties reported for people with lower limb absence.
- Detail the rating of each publication against the COSMIN risk of bias tool, to establish the quality of the studies that describe psychometric properties.
- Describe a process of stratification measures by an expert panel of outcome measure experts based on the current evidence of their psychometric properties.
- Detail a global consensus process of multidisciplinary clinicians, users, policy makers and researchers who have established a set of recommended outcome measures, based on their real-world experience and knowledge of outcome measure usability and usefulness.
- Present the final COMPASS, COMPASS+, COMPASS Adjunct and other recommendations including the use of a generic health related quality of life instrument.

Statement of the learning objectives
This symposium will describe the process of development and the outcomes of the global consensus, COMPASS, on outcome measure use for people with lower limb absence.

Advanced Instructional Course
Education

3.5.3
Modified Transfemoral Prosthetic Undergraduate Teaching in Response to the Coronavirus Pandemic

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Abstract
The National Centre for Prosthetics and Orthotics, University of Strathclyde and The Kobe College of Medical Welfare, Kobe, Japan are established educators in the training of prosthetists and orthotists throughout the world.

It is essential that prosthetic education programmes provide practical training to fulfil key learning objectives. Previously, practical elements of prosthetic courses were delivered using prosthetic service users. This is currently not possible under Covid restrictions.

To facilitate practical aspects of student training in a safe environment, alternative delivery mechanisms were devised to ensure students could still access and receive hands-on training on campus to fulfil learning outcomes.

To avoid the need to bring service users into the department to act as demonstration patients for clinical teaching mannequins have been specially designed and manufactured.

An overview of the module structure and aims at each training facility will be provided including the modified teaching approach. Teaching of modules has been delivered as a blend of remote learning (lectures and tutorials) and essential clinical and technical based learning using life like anatomical models of amputated limbs instead of patients (Gait assist LLC Japan). Video resources have been created and used to demonstrate prosthetic techniques. The use of personal protective equipment including facemasks and visors, and rigorous hygiene measures, ensures we have as safe a teaching environment as possible.

The session aims to share post-Covid experiences in Japan and the UK with other teaching establishments, to facilitate improved communication and enhance pedagogical techniques in training facilities worldwide.

Statement of the learning objectives
To share experiences and alternate methods of practical prosthetic teaching whilst reducing risk of exposure of Covid-19 to students and prosthetic users. A comparison of teaching methods will be explored in the UK and Japan.

Symposium
Prosthetics: Upper Limb

3.6.1
Best Practice and Advances in Adult Upper Limb Prosthetics

Simon Shaw[1], Laura Brady[2], Rachael Lovegrove[1], Gregory Bowring[3], Melissa Leong[3], Sean Nicklin[3], John O-Sullivan[4], Vincent MacEachen[5], Alix Chadwell[6]

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Abstract
Adult upper limb prosthetics has seen the introduction of new surgical procedures and a revolution in technological prosthetic options in recent years. How do we evaluate the potential benefits, ensuring optimal functional outcomes are achieved for individuals? Health systems differ in their ability to incorporate these advances, in part because of cost constraints, especially when cost-benefit analysis is lacking. It is timely to identify some key development and research priorities.

This symposium will present a summary of findings and collation of professional opinion regarding best practice from a collaboration between the ISPO-UK upper limb special interest group, prosthetic centres in the UK and another in Sydney, Australia. Presenters will cover multidisciplinary assessment, surgical procedures, Occupational Therapy assessment and training, and prosthetic provision to describe the experience incorporating the newer technologies, and the clinical reasoning underpinning decision points in the patient journey.

Statement of the learning objectives
Identify key areas of best practice in adult upper limb prosthetic rehabilitation
Identify key research priorities for further research
Reflect on the experience and challenges that affect service provision in different health systems

Free Paper Session
Orthotics: Lower Limb 1

3.6.2.a

Effect of Unilateral Ankle Plantar Flexor Weakness and Treatment with Ankle Foot Orthoses on Contralateral Leg Loading

Niels Waterval[1], Merel-Anne Brehm[1], Jaap Harlaar[2,3], Frans Nollet[1]

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BACKGROUND
A reduced ankle push-off power due to unilateral plantar flexor weakness often leads to quadriceps or knee joint pain in the unaffected leg. A reduced push-off power is expected to cause higher impact forces and knee adduction moments in the contralateral, unaffected leg, which can explain the experienced quadriceps and knee pain. Dorsal leaf ankle foot orthoses (AFOs) support the push-off power of the affected leg, which potentially can reduce the impact forces and adduction moments on the unaffected leg.

AIM
1) Determine whether impact forces and knee adduction moments are increased in the unaffected, contralateral leg of people with unilateral plantar flexor weakness compared to healthy individuals, 2) determine the effect of dorsal leaf AFOs on these forces and moments.

METHOD
Nine patients with unilateral plantar flexor weakness (median MRC: 4) were provided a dorsal leaf AFO. For walking with and without AFO, a 3D-gait analysis at comfortable speed was performed. Peak vertical ground reaction forces (GRF) during loading response and push-off, and knee adduction impulse for walking without AFO were compared with those obtained in a healthy control group. Furthermore, in patients, the effect of the AFO on contralateral leg loading was determined by comparing the parameters for walking with and without AFO.

RESULTS
Peak push-off GRF of the affected leg was significantly lower compared to that in healthy controls (9.3±0.4 vs 11.4±0.7 N/kg $p<0.001$). For the unaffected leg, peak vertical GRF in the loading response (12.0±0.9 vs 11.2±0.6 N/kg, $p=0.005$) and knee adduction impulse (0.26±0.05 vs 0.18±0.06, $p=0.002$) were significantly higher compared to healthy controls.

When using the AFO, walking speed increased from 1.05±0.17 to 1.16±0.15 m/s ($p=0.021$).

The AFO did not increase push-off GRF of the affected leg (9.3±0.4 versus 9.5±0.4 N/kg, $p=0.095$). For the unaffected leg, peak vertical GRF during loading response significantly reduced (from 12.0±0.9 to 11.4±0.7 N/kg, $p=0.017$), while a reduction in knee adduction impulse was only found when correcting for speed (without AFO: 0.22±0.04 vs with AFO: 0.19±0.05 Nm/kg/m, $p=0.009$).

DISCUSSION AND CONCLUSION
We demonstrated that in people with unilateral plantar flexor weakness, impact forces on the contralateral, unaffected leg are increased when compared to healthy individuals. Moreover, despite an increase in walking speed, dorsal leaf AFOs almost completely reduce these impact forces, including knee adduction impulse. This indicates that dorsal leaf AFOs have the potential to reduce contralateral joint pain and might contribute to the development of osteoarthritis.

3.6.2.b

A Novel Orthotic Ankle Joint Implemented in Stance Control Orthoses: Biomechanical Effect and Patient Benefit

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BACKGROUND

Orthotic ankle joints with an adjustable control of dorsiflexion and plantarflexion, enabling also an increased ROM, are well established in AFO fittings [1,2]. The use of this principle in SCOs for the fitting of patients with severe lower limb muscle weakness could result in enhanced functional options for an individually optimized orthotic treatment of this patient group.

AIM

The purpose of the study was to investigate the benefit a patient fitted with an SCO may expect from the new ankle joint principle when performing various walking motion patterns.

METHOD

Six patients (42±16years, 80±13kg, 171±7cm) fitted with an SCO (EMAG Active, Ottobock, Germany) including conventional orthotic ankle joints (CAJ) were enrolled in the study. Two weeks before starting the measurements, an orthotic ankle joint with the new principle (Nexgear Tango, Ottobock, Germany - NGT) was built into the SCOs.

In the lab session, the ADLs level walking (slow, medium and fast speed), walking with predefined short steps (0.4m) and ascending ramps were biomechanically analysed for both SCO/CAJ and SCO/NGT. Kinematic and kinetic parameters were recorded with an optoelectronic system (Vicon, Oxford, GB) and two force plates (Kistler, Wintherthur, CH).

RESULTS

The significantly increased dorsiflexion ROM for SCO/NGT (level walking appr. 4°, ascending ramps appr. 5°; $p \leq 0.05$) led to an increased reliability of switching from the locked to the unlocked SCO mode. This reliability was particularly increased both for short step walking and ascending ramps: correct switching in 81 % (NGT) vs 60% (CAJ) of all short steps and in 100% (NGT) vs 66% (CAJ) of all steps ascending ramps.

The greatest differences in kinetic parameters were measured for ascending ramps. For NGT, the mean ratio between deceleration and acceleration impulse, calculated from the horizontal GRF, is significantly decreased (0.9 vs 1.5, $p \leq 0.05$), indicating an improved roll-over behaviour with SCO/NGT. The orthotic side knee extension moment peak is significantly decreased for SCO/NGT (0.42 vs 0.50 Nm/kg, $p \leq 0.05$), enabling a reduced effort for swing phase initiation.

DISCUSSION AND CONCLUSION

From the biomechanical analyses, it can be concluded that the controlled and significantly increased ROM of NGT improves patients´ walking comfort for frequently changing sequences of various ADLs and uphill walking. Taking these demands into consideration, the use of the new orthotic ankle joint principle represents a new functional option to optimize an individual SCO fitting.

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3.6.2.c

Randomized Controlled Trial on Providing Ankle-Foot Orthoses After Stroke: Effects on Unaffected Lower Limb Kinematics

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BACKGROUND
Compensatory pelvis, hip and knee movements are reported after stroke to overcome insufficient foot-clearance. Ankle-foot orthoses (AFOs) are often used to improve walking post-stroke. Results from a randomized controlled trial on effects of early or delayed AFO-provision after sub-acute stroke showed that AFO-use properly corrected drop-foot, but that early or delayed AFO-provision did not influence affected pelvis, hip and knee kinematics after 26 weeks [1]. Whether AFO-provision influences lower limb kinematics of the unaffected side is unclear.

AIM
To study whether timing of AFO provision (early or delayed) after stroke influences lower limb kinematics of the unaffected side after 26 weeks, and whether there are group-by-time interactions over the 26-weeks period.

METHOD
Unilateral hemiparetic subjects with indication for AFO-use, maximal six weeks post-stroke were included. Subjects were randomly assigned to AFO-provision early (at inclusion, study week 1) or delayed (+8 weeks, study week 9). 3D gait-analysis (Vicon) with and without AFO was performed in randomized order at self-selected walking speed. Ankle, knee, hip and pelvis joint kinematics were measured at week 1, 9, 17 and 26 of the study (respectively T1, T2, T3 and T4). Independent samples T-test compared data of both groups after 26 weeks. Mixed-model repeated measures analysis within the early and delayed group quantified group-by-time interactions over the 26-weeks period.

RESULTS
Twenty-six subjects (15 early, 11 delayed) were included in the analysis. After 26 weeks, no significant differences were found between the early and delayed group for any of the joint angles, both with and without AFO. Changes in kinematics during the 26 weeks period did not differ between groups, except for hip flexion at foot-off (p=0.045). For the early group main changes were seen from T1 to T2, while the delayed groups showed changes incrementally over time.

DISCUSSION AND CONCLUSION
Current results indicate that early or delayed AFO-use post-stroke does not influence pelvis, hip and knee movements of the unaffected lower limb after 26 weeks. Together with results from effects on the affected side [1], one can conclude that AFOs should be provided to improve drop-foot post-stroke, but not with the intention to influence potential compensatory patterns around hip and pelvis.

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3.6.2.d

Effects of Specialized Care Orthoses on Walking and Personal Goals in Adults with Leg Muscle Weakness Due to Neuromuscular Disorders

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BACKGROUND

Leg orthoses enable people with neuromuscular disorders (NMD) to improve stability during walking and reduce walking effort and related fatigue. However, evidence for the effectiveness of orthoses to improve walking in NMD is still inconclusive [1,2], which might be partly explained by variations in the extent to which orthotic properties are matched to the individual [3]. Application of a treatment guide for the individualized provision of leg orthoses within a multidisciplinary expertise setting (specialized orthotic care) could improve treatment outcomes.

AIM

We aimed to evaluate effects of specialized care orthoses on walking energy cost, walking speed, attainment of personal goals and perceived walking ability in adults with NMD who experience walking problems due to leg muscle weakness.

METHOD

We retrospectively analysed data that were collected during orthotic practice in an outpatient orthosis expertise Rehabilitation clinic from 63 adults with NMD who experienced walking problems due to calf muscle and/or quadriceps weakness and were provided with a specialized care orthosis. We compared the specialized care orthosis after 3-months of use with the usual care orthosis at baseline on walking energy cost (in J/kg/m) and walking speed (in m/s) (assessed during a comfortable 6-minute walk test), attainment of personal goals (assessed with Goal Attainment Scales (GAS range: -3 to +2)) and perceived walking ability (assessed for 7 items scored on a 11-point scale).

RESULTS

The following specialized care orthoses were provided; dorsiflexion-restricting ankle-foot orthoses (AFOs) (n=16), locked knee-ankle-foot orthoses (KAFOs) (n=26) and stance-control KAFOs (n=21). Compared to baseline, specialized care orthoses did not significantly change walking energy cost (-0.07±0.83 J/kg/m, from 5.76±1.24 to 5.69±1.42 J/kg/m, p=0.52) or speed (-0.01±0.13 m/s, from 0.83±0.22 to 0.82±0.21 m/s, p=0.47). From available GAS scores of 42 individuals, 62% achieved at least one of their goals, defined as clinically relevant improvements (+2 points). Regarding perceived walking ability, specialized care orthoses significantly improved safety (5.46±2.06 vs 6.91±1.98), stability (4.55±2.17 vs 6.82±2.02), walking intensity (4.21±2.33 vs 5.71±2.25), walking irregular surfaces (2.52±2.01 vs 4.21±2.57), fear of falling (4.57±2.76 vs 5.66±2.99) and overall satisfaction (3.88±2.00 vs 6.25±2.21), all p<0.05.

DISCUSSION AND CONCLUSION

Specialized care orthoses improved perceived walking ability and personal goal attainment in individuals with NMD, compared to usual care orthoses at baseline. No differences were found in walking energy cost and walking speed, which may be explained by response differences between individuals (indicated by the large SD of the differences) using different types of orthoses, which needs to be further explored.

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3.6.2.e

The Effects of Stance-Control Knee-Ankle-Foot Orthoses on Walking Speed, Energy Expenditure and Satisfaction with Walking in Polio Survivors

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BACKGROUND

Polio survivors who suffer from quadriceps weakness often experience walking problems such as knee instability and related falling [1], reduced speed and increased walking energy expenditure [2]. Stance-control knee-ankle-foot orthoses (SC-KAFOs) can be provided to improve stability of walking. SC-KAFOs have a stance control knee joint that locks during the stance phase but permits knee flexion during swing, allowing a more natural gait pattern. So far, effectiveness of SC-KAFOs on improving walking ability in polio survivors has hardly been evaluated.

AIM

We aimed to evaluate the effectiveness of custom made SC-KAFOs provided in clinical care on walking speed, walking energy expenditure and satisfaction with walking in polio survivors with quadriceps weakness compared to walking with shoes only.

METHOD

We retrospectively analysed data from 28 polio survivors (18 males, mean age 54 years) without prior KAFO experience who were provided with a SC-KAFO during clinical care. The following assessments were performed at baseline (walking with shoes only) and at least 3 months after delivery of the SC-KAFO: a six-minute walk test with ambulant registration of gas-exchange to assess comfortable walking speed (m/s), walking energy consumption (J/kg/min) and walking energy cost (J/kg/m), and a questionnaire on satisfaction with walking (6 items assessed on an 11 point scale).

RESULTS

The mean (SD) walking energy consumption decreased significantly with 7% (-0.35 (0.52) J/kg/min) while walking with the SC-KAFO (4.28 (0.97) J/kg/min) compared to shoes-only walking (4.62 (1.02) J/kg/min, $p=0.006$). No differences were found in walking speed and energy cost ($p \geq 0.196$). Patients reported significant improvements on safety and stability during walking and walking satisfaction ($p<0.035$). Satisfaction with walking effort, stair climbing and fear of falling remained unchanged ($p>0.05$)

DISCUSSION AND CONCLUSION

To our knowledge this is the largest study so far evaluating the effects of SC-KAFOs. We found that in polio survivors with quadriceps weakness and no prior KAFO experience, custom made SC-KAFOs are beneficial in improving walking ability, as shown by a decreased walking energy consumption and an improved perceived walking safety, stability and satisfaction.

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Free Paper Session
Developing Countries: Rehabilitation Strategies

3.6.3.a
COVID19 and Clubfoot Treatment in 2020: Mitigating the Negative Impact Through Collaboration

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BACKGROUND
In 2020, providers of services for children born with clubfoot globally faced unprecedented challenges due to Covid19. Similarly to orthopaedic surgery, clubfoot providers faced delays and cancellations to treatment [1] and suspension of other programme activities such as training, community follow up and awareness raising. In order to reduce the long-term impacts clubfoot providers found ways to mitigate these factors including treatment adaptation, telemedicine and new approaches to training.

AIM
To understand the impact of Covid19 on clubfoot treatment and the mitigating factors shared amongst professional and NGO networks in lower and middle income countries (LMIC).

METHOD
This study used a mixed methods approach, drawing on data from a variety of sources to provide a wide breadth of information. Quantitative data on the impact on service delivery was gathered from a survey of all LMIC with >50 expected clubfoot cases/year, carried out in October 2020. Data analysis compared this with published data on expected cases/year and clubfoot service access in LMIC [2]. Qualitative data was gathered from meeting minutes with professional and NGO networks, collected between March 2020 – January 2021. Qualitative data was coded and analysed thematically.

RESULTS
The survey response rate was 67% by country. Clubfoot services were impacted for an average of 15 weeks, with service disruption at 65% during this time period. Service providers reported challenges due to Covid19 including: treatment delays and interruptions due to local restrictions and problems with patient attendance, difficulties with providing treatment safely due to factors such as inadequate clinic space, lack of PPE, lack of guidance on reopening services safely and disruption to wider clubfoot programme activities such as training, awareness raising and community follow up. Through a facilitated, collaborative network treatment providers were able to find and share mitigating solutions to some of the challenges, such as treatment adaptation, optimising Foot Abduction Brace provision, creating new guidelines and sharing existing guidance, use of telemedicine and blended learning approaches.

DISCUSSION AND CONCLUSION
The impact of Covid on clubfoot treatment provision is likely to result in children experiencing sub-optimal treatment outcomes or missing out on treatment altogether. However, service providers have found ways to adapt and mitigate negative impacts. A facilitated, collaborative network provided a platform for sharing guidance, adaptations and innovative solutions. The qualitative data represents a relatively small, homogenous sample but is a rich source of information which may be generalisable to other conditions and settings.

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3.6.3.b
Diabetic Foot Care Training of Trainers During a Pandemic

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BACKGROUND
In the 48-bed general surgery ward at the National Referral Hospital (NRH) in Honiara, Solomon Islands, at least 60% of inpatients have severe diabetic foot wounds, requiring significant surgical and medical intervention and long healing times [1]. Global mortality rates 5-years post amputation are estimated at 56-70% [2]. The accelerating growth of the diabetes epidemic is causing frightening health and economic burden. COVID-19 has forced delivery of in-person diabetic foot care training to adapt to a remote and 100% online environment.

AIM
To adapt in-person diabetic foot care Training of Trainers to an online learning environment in response to COVID-19 preventing in-person training. The overall goal is to strengthen health service capacity in Solomon Islands to reduce avoidable wounds, amputations and deaths.

METHOD
100% online training was delivered through an open access platform. Electronic tablets and internet data were provided to each training participant (n=3). The course consists of three parts:

- Wound management, infection control and offloading
- Diabetes education, diet and lifestyle
- Training of trainers

Delivery was via modules, quizzes, service forms, discussion forums and fourteen step-by-step instructional videos for practical components. 3D printed foot models with life-like wounds, blood and macerated skin were used as training tools to practice wound debridement and offloading methods. Diabetic foot care is highly practical and sessions were complemented with mentoring and supervision. Complex cases from participant's clinics were explored using 3D feet models.

RESULTS
Participants rated course delivery and content an average of 4.7 stars out of 5. All participants reported their understanding of wound healing and offloading to be 'significantly better than before'. Infection control, two participants reported 'significantly better than before' and one 'better than before'. Participants stated theory and mentoring had significantly improved their confidence in offloading, however, if they were to apply offloading devices to a client, in-person supervision would be required. A pre-and post-course examination was completed by all participants with an average of 118% improvement in grade. Service forms with key indicators were introduced into the service to improve data collection. Remote delivery has allowed participants to join training sessions over a longer period of time without interfering with work duties, compared to, regular two-week intensive in-person training.

DISCUSSION AND CONCLUSION
Remote delivery has advantages and disadvantages, overall, the course has been successful in learning outcomes and cost effective. Future improvements to technology and training tools such as telehealth and the 3D feet developed by UniSA will create more opportunity to strengthen remote training delivery. Motivation Australia recommend exploring future opportunities for online delivery of theoretical components. This must be complemented by in-person practical sessions for applying newly introduced practical activities such as offloading in a clinical setting.

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3.6.3.c
The Societal Value of Prosthetic Rehabilitation in Nepal

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BACKGROUND
Limb amputation severely impacts the quality of life (QoL) of a person and diminishes both their mental- and physical functioning. As a consequence, participation levels in work- educational- and social activities are decreased with subsequent losses for society. Successful prosthetic rehabilitation (SPR) has the potential to facilitate improvements in functioning and support reintegration of amputees into society. Accordingly, it was hypothesized that SPR can overcome the societal losses that resulted from amputation and can thus have societal value.

AIM
This study aimed to identify the potential pathways in which SPR results in societal value in Nepal, in order to lay a foundation for a future tool to measure and quantify the societal value of SPR in Nepal.

METHOD
To reach the study aim, a literature review was conducted to identify existing pathways in which SPR can lead to societal value. A QoL framework, consisting of the different factors that influence the QoL of amputees, was used to guide this search as it was hypothesized that SPR has the potential to improve or overcome such factors. To translate the findings from the literature to the Nepalese context, interviews were conducted with Nepalese beneficiaries from Humanity & Inclusion Nepal. The interviews were semi-structured, and a preliminary topic list was used based on themes identified during the literature review.

RESULTS
According to the literature, of which most studies were conducted in high-income settings, improvements in mental- and physical functioning can increase productivity levels and the likelihood for employability, and decrease absenteeism, healthcare utilization, and dependency on social services. The associated societal value can be measured through employability levels, productivity levels, absenteeism rates, healthcare utilization, and dependency on social services. In Nepal, lacking social security, job security, and health insurance coverage create difficulties in measuring societal value through those same mechanisms. There is a greater necessity for prosthetic devices and a large interdependency within communities. The health and well-being of an amputee thus greatly influences the health and well-being of the people in their surroundings, creating societal value in different ways than proposed by the literature.

DISCUSSION AND CONCLUSION
To conclude, means of measuring the value of improved functioning in high-income settings were found to be incompatible with the Nepalese setting. A measurement tool for societal value in Nepal should focus on the societal value beyond the individual. Further research is needed to strengthen the body of evidence on the importance of prosthetic rehabilitation. Additionally, investments must be made into the preconditions for SPR to result in societal value, such as availability, accessibility, and quality of prosthetic rehabilitation services.

3.6.3.d

How to Establish and Coordinate a Rehabilitation Technical Working Group (RTWG) to Develop a National Rehabilitation Strategy

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BACKGROUND
Rehabilitation is regarded an essential part of the continuum of care for most government health ministries. Therefore, rehabilitation services need to be well integrated into a government's health system. The World Health Organisation's (WHO) Guide for Action to strengthen rehabilitation in health systems recommends establishing a Rehabilitation Technical Working Group (RTWG) comprising all key rehabilitation stakeholders, to develop, implement, monitor and evaluate national rehabilitation strategy for a country.

AIM
To inspire countries with emerging health systems to develop a national rehabilitation strategy by sharing the experience of the International Committee of the Red Cross (ICRC) in East Africa, in establishing and coordinating such a technical working group.

METHOD
The ICRC worked in partnership with Health Ministries in East Africa (Tanzania, Zambia, and Rwanda) to establish and coordinate a RTWG to develop a national rehabilitation strategy. A Terms of Reference (ToR) document was compiled for each RTWG, detailing the present rehabilitation context, the key development objectives, the policy aims of the government, the RTWG's scope of work, membership criteria, roles and responsibilities. RTWG membership included the focal persons for rehabilitation from the Health Ministry, other relevant government agencies, rehabilitation service providers, service user groups, professional associations, academia, nongovernmental organizations and other development partners. The Ministry of Health took the lead role of the RTWG with support from ICRC.

RESULTS
RTWG members provided technical inputs, engaged and contributed to the conduct of a Systematic Assessment of Rehabilitation Situation (STARS) using WHO developed tools such as the Template for Rehabilitation Information Collection (TRIC) and Rehabilitation Maturity Model (RMM). WHO rehabilitation consultants led the country assessment to produce the STARS report. The Health Ministry then used the STARS report recommendations to develop a national rehabilitation strategy and monitoring framework. The RTWG played a significant role in the process of identifying rehabilitation needs, resource availability, setting progress indicators and drafting a priority action plan for strengthening rehabilitation in the health system. Task related sub committees were created to reflect the six building blocks of the health system – leadership and governance, finance for rehabilitation services, human resources and infrastructure, rehabilitation data management, service accessibility, and service quality.

DISCUSSION AND CONCLUSION
The RTWG is essential to developing a comprehensive national rehabilitation strategy and monitoring / evaluation framework. However, support from development partners, like the ICRC, can be needed to initiate, support and coordinate the process. The RTWG's scope is not limited to the development and implementation of a national rehabilitation strategy but can extend to the creation of national guidelines and protocols for rehabilitation service provision.

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ACKNOWLEDGEMENTS: USAID, NORAD, WHO, Ministries of Health in Tanzania, Rwanda and Zambia.

3.6.3.e
Donating Orthotic and Prosthetic Components to Low Income and Low to Middle Income Countries

Beth Sheehan[1], Sally Cavenett[2]

[1]ISPO Australia, Brisbane, Australia. [2]ISPO Australia, Adelaide, Australia

BACKGROUND
ISPO Australia supports provision of prosthetic and orthotic services both in Australia and in low and low to middle income countries within the Pacific region. The standards set by the World Health Organisation's (WHO) Standards for Prosthetics and Orthotics (2017) [1], outline the minimum standards which the professionals within ISPO should be meeting in the provision of prosthetics and orthotics. However, inappropriately considered donations can be problematic and at times harmful to the intended recipients.

AIM
Provide advice for donating O&P components and devices for use in low income and low to middle income countries. It is not to discourage nor prevent the donation/use of donated items, but to ensure long-term safety and sustainability.

METHOD
The guidance document was created as a result of a long-standing relationship between ISPO Australia and the Pacific region and several enquiries and two donation shipments that ISPO Australia has had to manage. ISPO Australia's outreach committee drafted the document through lived experience and the research of key donation and medical supply documentation to produce a detailed document to support donations within the wider region. Consultation with key partners, and consideration of the multiple audience recipients were included in the approach of authorship for this document.

RESULTS
The outcome has been a highly detailed document that encompasses appropriate donation procedures under Australian governance whilst acknowledging the need for a low-level document that can be shared with donors, recipients and the wider orthotics and prosthetic community and stakeholders.

DISCUSSION AND CONCLUSION
Within the research it was clear that there is limited documentation about the donation of prosthetics, orthotics and the relevant componentry. This document is one of the first of its kind.

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ACKNOWLEDGEMENTS: Thank you to AOPA, Motivation Australia, ARATA and Narelle Cook for the feedback for the final documentation.

Thursday, 4 November

Keynote Lecture

4.0
Digital Workflows for Predictive Prosthetic Socket Design (or Why I'm Glad I Made Friends with Prosthetists and Prosthesis Users)

Alex Dickinson

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Abstract

Prosthetic socket design depends on the skill and experience of highly trained professionals. This skill, experience and training equip them for a highly challenging design task: the residual limb-socket interface is a moving target due to soft tissue healing and adaptation, volume fluctuation and, not least, the dynamics of gait. Socket design benefits from iteration and feedback between the limb user and the prosthetist, and while some iteration is inevitable as the soft tissues heal and functionally adapt to their dramatically altered load-bearing role, excessive iteration as 'trial and error' has economic costs to service providers, and is inconvenient to limb users.

My research team's aim was to develop biomechanical simulation-based socket design methods which will support prosthetists in producing comfortable prosthetic sockets in fewer iterations, whilst keeping the expert clinician and their client at the centre. We set out to investigate whether software tools could be built that would be compatible with CAD/CAM workflows to enable prosthetists to appraise their design using predictions of socket-limb pressure and soft tissue strain, biomarkers of discomfort and tissue injury. Such structural analyses have developed over 40 years but have not been adopted clinically. To try and avoid our work ending with scientific publications alone, we set ourselves the challenge that these tools should not require high performance computers, long calculation times, high cost software or a mechanical engineer.

This talk will describe how we have tried to reframe prosthetic socket design in the paradigm of formal engineering design, whilst aiming to make simulation-based design tools usable and accessible to clinicians. I will describe how we used population-statistics methods to obtain predictions in real-time, and the challenges in understanding the loads these vulnerable soft tissues can sustain. I will share examples of how in future we might employ optimisation methods in a responsible way, and how we could use these statistical methods more widely, for example to identify guidelines for using novel socket materials. Most importantly I will share what we learned from involving clinicians, psychologists, health scientists and patients in our research – it is for them.

Symposium
Prosthetics: Upper Limb

4.1.1
Design of Fit-For-Purpose, and Fit-For-Context, Purely Mechanical Upper Limb Prostheses

Alix Chadwell[1], Maggie Donovan-Hall[2], Robert Ssekitoleko[3], Mohammad Sobuh[4], Ali Hussaini[5], Brenda Nakandi[3]

[1]University of Salford, Salford, United Kingdom. [2]University of Southampton, Southampton, United Kingdom. [3]Makerere University, Kampala, Uganda. [4]University of Jordan, Amman, Jordan. [5]University of Portsmouth, Portsmouth, United Kingdom

Abstract
Research in upper limb prosthetics largely focuses on electrically powered, multi-degree of freedom devices, which are costly, and require access to reliable charging points and specialist maintenance services, making them difficult to deploy in many lower and middle income settings. Further, rejection rates remain stubbornly high. Purely mechanical prostheses are potentially simpler to manufacture and maintain, may offer significant functional restoration; but current designs are costly, many are uncomfortable and some may not be aesthetically acceptable.

A multi-disciplinary approach is needed to address the complex design, and context-specific challenges, and hence move towards prosthesis designs which are both accessible, and of clear and sustained value to the user. In this symposium we will illustrate how our team have tackled these problems as part of the Fit4purpose upper limb prosthetics project, involving partners in the UK, Uganda and Jordan.

The symposium will address:

1. **Capturing the context for designers.**
    - Users' experiences and requirements
    - Prosthetics services, including repair services

2. **Design and evaluation of user-informed prosthetic hands and sockets**
    - Specification development
    - Semi-passive hand designs and the function/appearance trade-off in LMICs
    - Sockets - challenges and potential appropriate solutions

3. **Translation into practice – Supply chain issues faced by innovators in prosthetic devices**
    - Supply chains for P&O products in Uganda
    - Integration with NGO and other services

4. **Lessons learnt**
    - Key learning points and ways forward

Statement of the learning objectives
This symposium will provide an overview of multi-disciplinary approaches needed to address the major challenges of designing upper limb prosthetic devices which may be both accessible and of real value to the user.

Free Paper Session
Orthotics: Lower Limb 2

4.1.2.a
Quick Release Mechanism for a Posterior Strut Ankle-Foot Orthosis to Enable Strut Swapping

Wentao Li[1], Edward Lemaire[1,2], Natalie Baddour[1]

[1]University of Ottawa, Ottawa, Canada. [2]Ottawa Hospital Research Institute, Ottawa, Canada

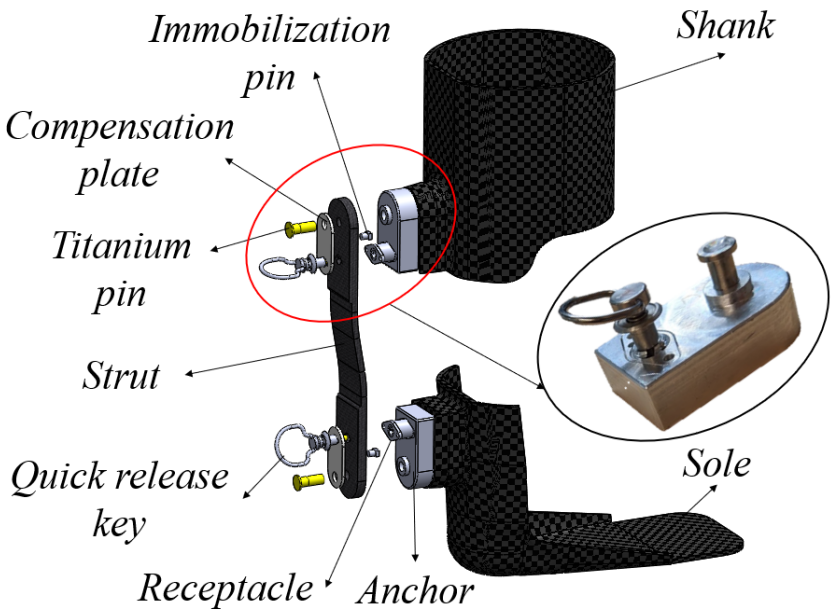
BACKGROUND
Posterior dynamic element ankle-foot orthoses (PDEAFO [1]) use a carbon fibre strut to store and release energy, which can improve mobility but limit ankle movement. Users may want to change AFO stiffness based on their current activity, such as driving or playing a sport. However, swapping would be time-consuming and impractical in daily living since current PDE AFO use Loctite bolts to connect the strut to the orthosis. A new approach is needed to enable fast strut swapping.

AIM
Design, prototype, and evaluate a new quick-release mechanism (QRM) that allows users to easily change posterior strut elements without tools to change AFO stiffness.

METHOD
A novel mechanical QRM design was created and modelled in SolidWorks. A prototype was produced and mechanical tested under running and downhill walking loads (Instron 4482). QRM-AFO swap time was verified with four able-bodied participants, using a 3D printing AFO with the QRM and another with typical bolt attachment.

RESULTS
The new QRM-AFO consisted of an orthosis shank, orthosis foot plate, quick release mechanism, and strut (Figure 1). Simulated stress on the titanium pin, anchor and quarter-turn fastener, under maximum load, did not exceed the yielding stress after multiplying the safety factors. Mechanical testing verified the simulation result since no visible failure or measurable plastic deformation occurred under running and downhill walking load. The QRM and 3D printed AFO worked smoothly with no interference. The time for participants to swap struts averaged 25.01 ± 3.66 seconds, outperforming the 60.48 ± 10.88 seconds result for the hand-tightened bolted strut. A learning evaluation with one participant showed that, after approximately 30 swapping iterations, swap time was consistently below 10 s.

Figure 1. Quick release ankle foot orthosis



DISCUSSION AND CONCLUSION
The QRM design was sufficient to support participants during daily activities and enabled strut swapping below 10 s, after a 30 iteration learning period. This is an important AFO design that allows a person to effectively change stiffness to accommodate their need. For example, very low or no stiffness when driving, moderate stiffness for walking, and optimal energy return for sports. Since no tools are needed, the person would only need to have to carry or store the different struts.

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4.1.2.b

Effects of Ankle Foot Orthosis Design on the Pressure and Microclimate Between the Device and Limb

Emily Kelly, Alex Dickinson, Peter Worsley

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BACKGROUND

Ankle foot orthoses (AFOs) may cause tissue damage due to high pressure and shear at the skin interface [1]. Microclimate factors (elevated temperature and humidity) are also understood to increase tissue vulnerability [2]. Understanding how different AFO designs affect the conditions between the limb and orthosis may guide device design criteria to reduce tissue damage risk and improve satisfaction.

AIM

To investigate the effect of two different AFOs and sock materials on the pressure, temperature, and relative humidity (RH) at the limb-orthosis interface.

METHOD

Ethical approval was granted to test Extra Strong (ES) and Push AFOs (OrthoEurope, UK) in 10 participants wearing bamboo or cotton socks. Participants had to be healthy and aged 18-60. For each AFO/sock combination, participants completed 15-minute treadmill walk and quiet standing sessions with 15-minute recovery periods between. Plantar pressures were measured at the AFO (F-Scan, USA) and temperature and RH (Sensirion SHT75, Switzerland) were measured at the skin at strategic locations. An average map of stance-phase pressure data was calculated for each condition and used to compare different pressure parameters. The temperature and humidity values were compared between the start and end of each test condition.

RESULTS

Temperature, RH and rearfoot plantar pressure gradients were compared between conditions for the first 5 participants. The Push AFO data revealed lower pressures (in 4/5 participants) and higher temperatures (3/5 participants) than the ES orthosis. In 3/5 participants, temperature was higher for the bamboo sock than cotton. RH results were more mixed between participants and test sessions and seemed to be dependent on device design, with higher humidity observed in foot regions with greater coverage. The median rearfoot peak-pressure-gradients were dominated by the orthosis, and markedly higher for the ES (IQR 35-69kPa/mm) than the Push (IQR 28-38kPa/mm). Similar trends were found for peak pressure and time-pressure integral results.

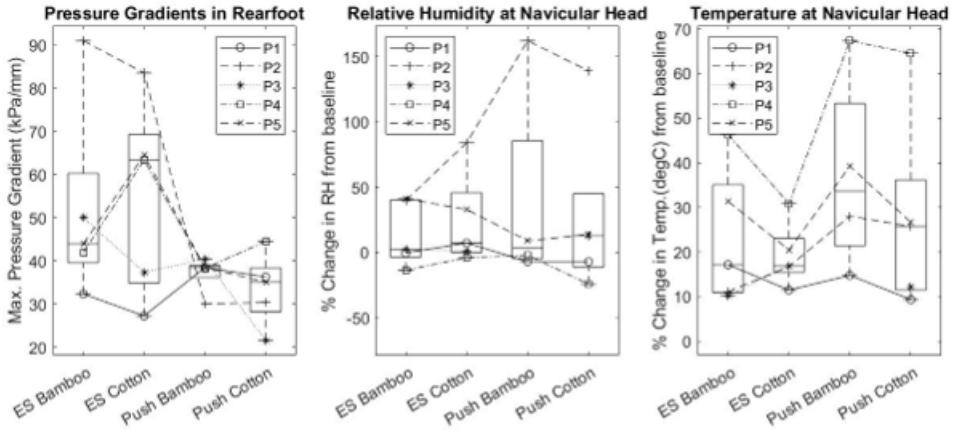

Figure 1: First five participants results, displaying maximum rearfoot plantar pressure gradients during gait and the percentage change from baseline of temperature and RH at the navicular head

DISCUSSION AND CONCLUSION

Ambient microclimate was not controlled between test sessions, and recruitment was interrupted by COVID-19 after five participants. However, these initial results clearly show how orthosis design and sock material can affect the device-skin interface conditions and so should be considered when trying to optimise device design and skin safety.

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ACKNOWLEDGEMENTS: Funding: EPSRC(EP/N509747/1, EP/N02723X/1), RAEng(RF/130).

4.1.2.c

Efficacy of a New Ankle Foot Orthosis on Knee Adduction Moment and Clinical Parameters in Individuals with Medial Knee Osteoarthritis

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BACKGROUND
A new strategy for reducing knee adduction moment, in people with knee osteoarthritis, is to alter the position of the centre of pressure under the foot with an ankle-foot-orthosis that is rigid in the frontal plane [1]. However, ankle inversion is believed to be essential to maintain the medio-lateral balance [2]. Usage of an ankle foot orthosis which could prevent the ankle eversion while allowing ankle inversion may augment the knee joint alignment modification without disturbing the medio-lateral balance.

AIM
The aim of this study was to compare the new ankle-foot-orthosis and a lateral wedge insole in terms of the biomechanical and clinical outcomes in people with knee osteoarthritis.

METHOD
A cross over randomized design was used where 31 individuals with medial knee osteoarthritis wore each intervention for two weeks, with two weeks washout between the interventions. Three-dimensional kinematic and kinetic data and clinical outcomes were collected to evaluate the effects of each intervention on knee adduction moment, pain, stiffness, and function.

RESULTS
The new ankle-foot-orthosis and lateral wedge insole significantly improved pain and function, and reduced the knee adduction moment. However, the new ankle-foot-orthosis resulted in more knee adduction moment reduction and function improvement compared to the lateral wedge insole.

DISCUSSION AND CONCLUSION
The results of this study have shown that both orthoses have a potential role in conservative management of medial knee osteoarthritis. The new ankle-foot-orthosis proved better at improving function and knee adduction moment; though other clinical outcomes were the same as the lateral wedge insole.

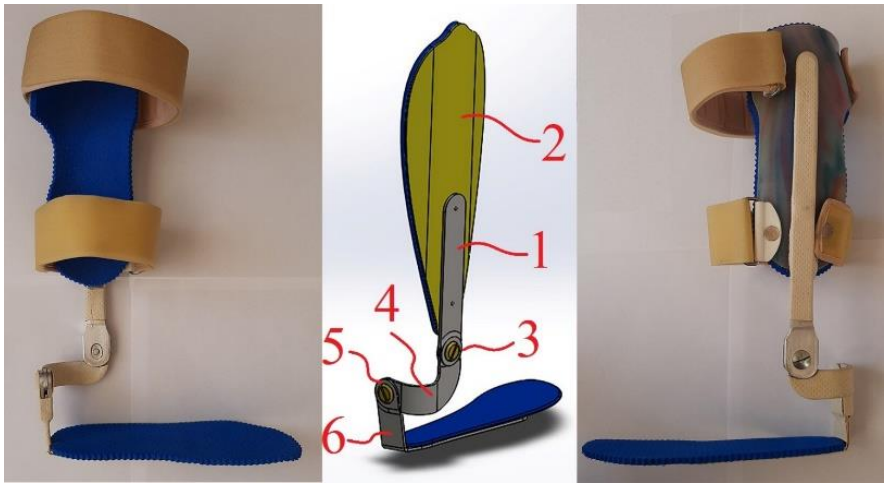

Figure 1 The new AFO used in this study. (1) shin bar, (2) shin shell, (3) lateral hinge, (4) intermediate bar, (5) posterior hinge, (6) foot part.

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ACKNOWLEDGEMENTS: This study was financially supported by the Iran University of Medical Sciences and the Iranian National Science Foundation.

4.1.2.d

Effect of Equipping an Unloading Knee Orthosis with Vibrators on Biomechanical and Clinical Parameters in People with Medial Knee Osteoarthritis

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BACKGROUND

Unloading knee orthosis is prescribed for people with medial knee osteoarthritis to unload the damaged compartment. However, despite its benefits, using knee orthoses can reduce knee muscle activity in people with various disorders [1-3], which may result in muscular atrophy in the long-term. Muscular atrophy will boost the knee osteoarthritis development and progression rate. Local muscle vibration stimulation is an experimental method to increase muscular activity and alleviate pain and stiffness, and improve function in people with knee osteoarthritis [4-6].

AIM

This study sought to determine whether equipping an unloading knee orthosis with local muscle vibrators improves its effectiveness in reducing the knee adduction moment.

METHOD

The authors performed a clinical evaluation using the WOMAC questionnaire and instrumented gait analysis on 14 participants (seven participants wearing vibratory unloading knee orthoses and seven participants wearing conventional unloading knee orthoses) with medial knee osteoarthritis in two testing sessions: before wearing the orthosis and after 6 weeks of use. The authors performed each testing session under two conditions: braced and unbraced

RESULTS

Wearing both orthoses for 6 weeks significantly improved ($p < 0.05$) pain, stiffness, and function compared to the baseline assessment. There was a significant difference between the interventions in changing the first peak knee adduction moment ($p = 0.008$) and knee adduction angular impulse ($p = 0.009$) between the unbraced conditions in the two sessions. There was a significantly greater reduction in the first peak knee adduction moment ($p = 0.016$) and knee adduction angular impulse ($p = 0.008$) in the vibratory unloading knee orthosis than in the conventional knee orthosis in the second session

DISCUSSION AND CONCLUSION

Equipping the unloading knee orthosis with vibrators can improve its effectiveness in reducing the knee adduction moment and can prevent the side effects of its long-term use. Furthermore, equipping the unloading knee orthosis with the vibrators did not interfere with its effectiveness on pain, stiffness, and function.

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ACKNOWLEDGEMENTS: This work was supported by the Iran University of Medical Sciences and the Iranian National Science Foundation.

4.1.2.e

AFO Preference after Using an AFO with a Multi-Adjustable and a Blocked Ankle Joint in Patients Poststroke

Ana Maria von Corvin-Wiersbitzki[1,2], Barbara Montagnana[3], Mirco Bendinelli[4]

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BACKGROUND

Patient's AFO preference and their involvement in the treatment decisions positively influence compliance improving the rehabilitation outcome [1]. Similarly, physiotherapy that includes multiple repetitions of physiological movement in everyday situations may result in a neuroplastic long-term recovery of motoric function [2]. Thus an AFO that sustains normal gait with an articulated, resistance adjustable and range of motion (ROM) controlled ankle joint not only prevents gait compensations but could lead to permanent recuperation poststroke with continued use.

AIM

This case series evaluates the patient's preferred setting in poststroke patients after four weeks using a blocked AFO and a ROM regulated ankle joint with plantar and dorsiflexion assistance/resistance function and emphasizes the importance of empowerment in rehabilitation.

METHOD

Four poststroke patients were assessed using an articulated AFO with alignment, ROM limitation and resistance/assistance adjustability. Three tests were performed in a non-randomized order: 1. Baseline with standardized shoes; 2. Blocked AFO; 3. The same AFO with limited ROM and assistance/resistance of plantar and dorsiflexion. The patients had four weeks familiarization time in each setting and adjunct physiotherapy five days per week during the research period. The preferred setting was appraised through a questionnaire after the second and third trials; and another questionnaire upon completion. The L-Test for functional mobility and a 3-D analysis for kinematic and kinetic data were also performed following each trial.

RESULTS

After wearing the blocked AFO most subjects felt improved forefoot clearance in swing and an increase in velocity. At completion, three patients preferred wearing the AFO with ROM and one would wear either AFO. The external knee flexion moment at loading response was better with the ROM controlled AFO in the three patients that favoured a moving joint compared to a solid ankle. The L-tests reveal a reduction in the time required for functional activities independent of the AFO setting. Similarly, an increase in velocity, cadence and stride length was recorded in both AFO conditions at a self-selected speed. Physiotherapy was decisive in obtaining positive results particularly with the ROM-controlled AFO. The most compliant patient had also the best kinetic curve when controlled ankle movement was allowed.

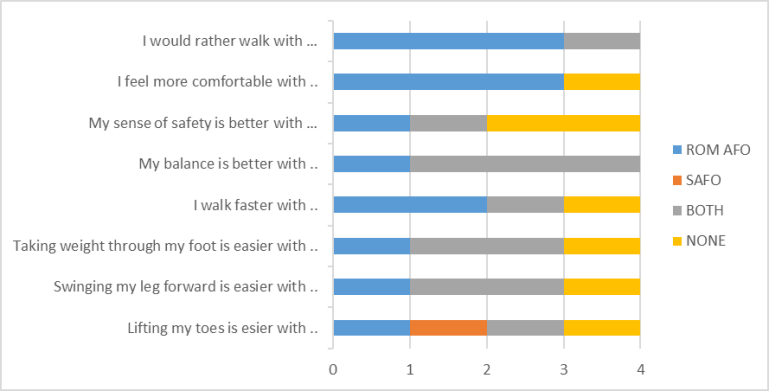

Figure 1. Preferred AFO setting at completion of study.

DISCUSSION AND CONCLUSION

Patients preferred the AFO with controlled ankle movement and felt it was more comfortable during ambulation. These perceived benefits may be associated with the diminished external flexion moment at loading response caused by the plantar flexion resistance spring of the multi-adjustable ankle joint and the dorsiflexion limitation at terminal stance. Empowerment increases compliance and together with the repetitive training of normal movement in dailiy living activities, may lead to long-term recuperation of the motoric function by promoting neuroplasticity after stroke.

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ACKNOWLEDGEMENTS: FIOR & GENTZ GmbH provided the NERUO SWING ankle joints for this case series.

Free Paper Session
Outcome Measurements

4.1.3.a

Alternative Scoring and Psychometric Evaluation of a Briefer Version of the Southampton Hand Assessment Procedure (SHAP)

Linda Resnik[1], Matthew Borgia[1], Jill Cancio[2], Jemy Delikat[3]

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BACKGROUND
Assessment of terminal device function is critically important to evaluating the prosthetic devices and prosthetic training. The 26-item Southampton Hand Assessment Protocol (SHAP) is an increasingly popular albeit burdensome, measure of prosthetic hand function that generates an Index of Functionality (IOF), and prehensile pattern (PP) scores.[1] Prior researchers identified potential issues in SHAP scoring and alternative scoring methods (e.g. LIF and W-LIF).[2]

AIM
Psychometric evaluation of the SHAP IOF, LIF, and W-LIF and PP scores, development and evaluation of the Prosthesis Index of Functionality (P-IOF).

METHOD
We examined item completion, floor/ceiling effects, concurrent, discriminant, and construct validity of SHAP IOF and alternative scoring methods in a sample of 126 persons with upper limb amputation. Structural validity was assessed with factor analysis. The P-IOF used longer boundary limits per item, and information from item completion and completion time. Calibration used a nonlinear mixed model. The P-IOF score was estimated using maximum a posteriori Bayesian estimation. Mixed integer linear programing (MILP) informed development of a shorter measure.

RESULTS
Mean age of the sample was 57 (sd 15.8), and 69% had transradial amputation. Floors effects were observed in 18.3-19.1% for the IOF, LIF, and W-LIF. Ten items were not completed by >15% of participants. Boundary limits were problematic for all but 1 item. SHAP scores were all strongly correlated with other dexterity measures (r=0.54-0.73). All scores were significantly better in the transradial group than for more proximal amputation (p>0.0001). Factor analysis did not support use of PP scores. The P-IOF used expanded boundary limits to decrease floor effects. Factor analysis of the P-IOF found acceptable fit (TLI≥0.9, RMSEA<0.08). MILP identified 10 items that could be dropped. The 16-item P-IOF had reduced floor effects (<7.5%), strong correlations with concurrent measures (r=0.55-0.77), and low correlations with discriminant measures(r=0.15-0.31). P-IOF reduced administrative burden by 9.5 (sd 5.6) minutes.

DISCUSSION AND CONCLUSION
Floor effects limit a measure's ability to distinguish between persons with low function. Our analyses supported the validity of the SHAP IOF, LIF, and W-LIF, but identified large floor effects, as well as issues with structural validity of the PP scores. The 16-item P-IOF minimizes floor effects and reduces administrative burden while maintaining strong evidence of concurrent and discriminant validity, and construct validity.

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4.1.3.b

Exploring Outcome Measurement Following Lower Limb Amputation From A Clinical Practice Perspective: A Narrative Review

Chantel Ostler[1,2], Helen Scott[3], Imad Sedki[4], Sisary Kheng[5], Maggie Donovan-Hall[2], Alex Dickinson[2], Cheryl Metcalf[2]

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BACKGROUND
Outcome measurement is essential to understand how our patients are progressing with their rehabilitation and to evaluate the performance of our services. Despite the potential value of this information, routine outcome measurement following lower limb amputation has failed to become embedded in clinical practice. Guidance from clinical interest groups, alongside national policy recommendations, has attempted to increase uptake, and examples of successful system-level routine outcome measurement programmes exist in other health care specialities, demonstrating what could be achieved.

AIM
To explore the current outcome measurement evidence base, in the context of prosthetic rehabilitation, to identify and understand barriers to implementation of outcome measurement in clinical practice and ascertain areas for future work.

METHOD
A narrative approach was used to allow for a broad exploration of the outcome literature within the prosthetic rehabilitation evidence base. A literature search of four databases was undertaken, following the PRISMA principals appropriate to narrative reviews, and using the search terms outcome, measure*, tool, scale, instrument, prosthe*, amput* and limb loss. 1116 papers were identified. 78 articles were selected for full text review alongside an additional 11 identified from manual searches of reference lists and grey literature sources. Following screening 35 papers were included in the review.

RESULTS
Four themes were identified from the literature search. The first theme focuses on understanding what outcomes need to be measured to capture meaningful success following prosthetic rehabilitation, and the second explores how these potential outcomes could be measured and examines existing measurement tools. The third theme illustrated barriers and facilitators of outcome measurement practice amongst healthcare professionals in clinical settings and the final theme highlights existing examples of routine outcome measurement within the field, and what lessons can be learnt for future ventures.

DISCUSSION AND CONCLUSION
Successful outcome measurement implementation in prosthetic practice is complex and multifaceted. Understanding the ‘why’, ‘what’ and ‘how’ of outcome measurement and embedding value at every step is key to success. Future work should consider all barriers to implementation and engage with patients and stakeholders to overcome them. Clinician-led outcome measurement practice, undertaken in partnership with academia, and focused on making outcome measurement valuable to prosthetic rehabilitation services, could then be developed with the aim to evidence and improve clinical practice.

ACKNOWLEDGEMENTS: Funding: EPSRC (EP/R014213/1), HEFCE, and University of Southampton Institute for Life Sciences.

4.1.3.c

The Me-Amputee Study: Exploring Meaningful Outcomes of Recovery Following Lower Limb Amputation and Prosthetic Rehabilitation: The Patient's Perspective

Chantel Ostler[1,2], Maggie Donovan-Hall[2], Alex Dickinson[2], Cheryl Metcalf[2]

[1]Portsmouth Hospitals University NHS Trust, Portsmouth, United Kingdom. [2]University of Southampton, Southampton, United Kingdom

BACKGROUND
There is currently a well-documented lack of consensus around how to measure outcome following lower limb prosthetic rehabilitation, and many different tools are available capturing a variety of outcome domains. This uncertainty reveals a lack of consensus not only in 'how' to measure outcome but perhaps more importantly, 'what' outcomes should be measured in the first place. Although prosthetic users will have a unique insight into what these important outcomes could be, little is currently known about their critical viewpoint.

AIM
The aim of this study was to explore what people who have undergone a lower limb amputation feel are meaningful outcomes following prosthetic rehabilitation.

METHOD
A qualitative methodology was used to allow in-depth exploration of what success means to prosthetic users, and what outcome domains capture it. Patient and public involvement (PPI) was used throughout to inform the research design, develop participant information and semi-structured interview guides.

37 participants were recruited from UK limb fitting centres and social media. Participants were included who had undergone a lower limb amputation in the last five years, and had completed rehabilitation with a prosthesis. Data were collected using focus groups and interviews.

Thematic analysis was used to analyse the data and member checking was undertaken, using a lay summary, to gain feedback and verify study themes with participants.

RESULTS
Five themes were identified that seek to encompass what prosthetic users feel are important outcomes following prosthetic rehabilitation. The ability to participate in important activities was highlighted as key but notably *how* participants were able to undertake these activities was also raised, i.e. independently, safely and with minimal equipment. Participants also prioritised a comfortable, easy-to-use prosthesis and discussed the importance of being able to manage their own pain. Adjusting and accepting their new normal was also integral to success and this was linked to being able to achieve the goals they set for themselves. A significant finding of this study was that these five themes, or outcome domains, did not exist in isolation for prosthetic users, but appeared to interact with each other, contributing to, or inhibiting their holistic sense of recovery.

DISCUSSION AND CONCLUSION
Understanding important outcomes that define what recovery means to people following amputation can help to inform the selection of outcome measures that evaluate prosthetic interventions in a more meaningful way. It may also challenge the single-domain approach we have historically used to design and utilise outcome measurement tools. We hope this will provide a unique patient led perspective as a first step towards consensus on the use of outcome measures, which is grounded in the experience of prosthetic users.

ACKNOWLEDGEMENTS: Funding: EPSRC (EP/R014213/1), HEFCE, University of Southampton Institute for Life Sciences and British Association of Chartered Physiotherapists in Amputation Rehabilitation.

4.1.3.d

The Self-Management Assessment for the Residuum and prosThesis (S.M.A.R.T.): A Novel Knowledge Assessment for Persons with Lower Limb Loss

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BACKGROUND

Persons with lower limb loss (PwLLL) require the ability to self-manage (SM) their residual limb, prosthesis, and the socket interface. Failure to SM can result in SM-related complications (SMRC) like skin breakdown or re-amputation. Health professionals use knowledge assessments to prevent SMRC associated with various chronic diseases. However, there are no valid and reliable SM knowledge assessments for PwLLL in publication.

AIM

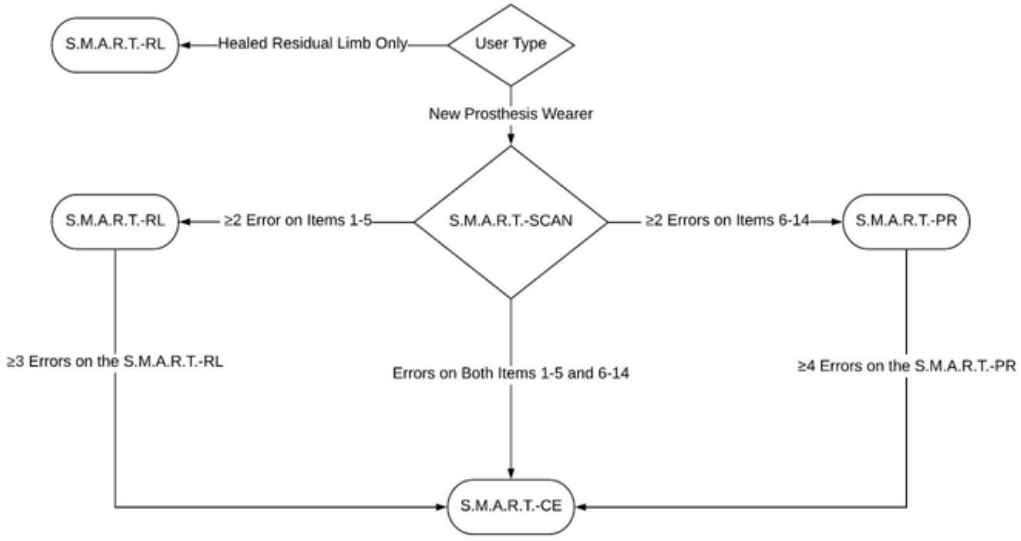
The aim of this study was to develop and validate a reliable knowledge assessment measure (along with corresponding targeted educational interventions (TEI)) for persons with lower limb loss.

METHOD

This study took place in four phases and utilized mixed methodology. Participants included PwLLL, prosthetists, and physical therapists. Phase 1 (n=23) involved a needs assessment of relevant stakeholders through semi-structured interviews. Phase 2 (n=59) was the development of the knowledge assessment measure, followed by face and content validation. Phase 3 (n=140) assessed reliability using Kuder-Richardson Formula 20 (KR-20), item difficulty, structure of the measure based on corrected total-item correlations, and formulation of sub-measures. Phase 4 (n=140) evaluated the discriminate construct validity of the measure using known groups comparison.

RESULTS

A 60-item dichotomous knowledge assessment was drafted from the codes of interviewed prosthetic users, prosthetists, and physical therapists. Face validity was high at a mean 4.49±.15/5.0 (90%) for the measure's readability, usability, perceived utility, and benefit to stakeholders. Four S.M.A.R.T. measures were validated: residual limb only, prosthesis use only, comprehensive examination, and a quick screening tool. To maximize clinical efficiency and reduce testing burden, the S.M.A.R.T. measures were integrated to minimize the number of items to be completed, triaging PwLLL according to their knowledge level and specific area of deficits (see figure). Internal consistency values ranging from .70-82, item difficulties (.63-.82.), CTC (.17-.43), and item lengths of 10-45 items across measures. All four measures demonstrated discriminant construct validity (P<.01) and clinically reliable KR-20 values (>.70). Covariation of education level and prosthetic use were non-significant.



DISCUSSION AND CONCLUSION

The S.M.A.R.T. is the first of its kind SM assessment validated for PwLLL that can be quickly and reliably administered by a prosthetist or physical therapist to identify SM knowledge gaps, then intervene with TEI focal to their deficit. The 14-item S.M.A.R.T.-SCAN can be used by clinicians to rapidly identify knowledge gaps in PwLLL, then based on their score be automatically triaged to more comprehensive modules. Future studies will expand to include the upper extremities, pediatrics, and specialty populations.

4.1.3.e

Methods Used in the Evaluation of Balance and Postural Control in Lower-Extremity Prosthesis Users: A Systematic Review

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BACKGROUND
Prosthesis users fall more often than individuals who do not use a prosthesis and previous research has indicated a link between balance and falls in this group [1]. There is a wide variety of methods used to investigate balance and postural control in prosthesis users. [2, 3] This variety makes the selection of methods challenging for both researchers and clinicians. Providing a summary overview of these methods' characteristics would help improve research and clinical practice related to prosthesis users.

AIM
To provide a critical synthesis of the quantitative methods used to evaluate balance and postural control in lower limb prosthesis users.

METHOD
A systematic search was conducted in 11 databases (Ageline, AMED, Cinahl, Cochrane, Medline, Proquest, PsycArticles, PsycInfo, PubPsych, Scopus, and Web of Science). Original peer-reviewed articles which quantitatively measured balance or postural control were included. Data were extracted and presented for issues related to; the name of the assessment; the instrumentation used e.g. force plates, motion capture; the outcome measure reported e.g. summary score, centre of pressure movement; the sample characteristics e.g. no. of participants, amputation level and; statements of reliability and/or validity of the test procedure/instruments in relation to the target population.

RESULTS
The summary included 179 articles assessing balance or postural control. The most common clinical test was the Berg Balance Scale and the most common method requiring lab-based instrumentation was the Limits of Stability test. Motion capture and the use of multiple force platforms were common. A large number of studies did not report the validity and/or the reliability of the chosen methods for the target study group. Commonly cited limitations related to small sample sizes and issues related to generalizability. The majority of participants were male unilateral transtibial amputees. Several studies did not discriminate between transfemoral and knee disarticulation amputation levels.

DISCUSSION AND CONCLUSION
The results suggest that research should endeavour to use and/or report on the validity and reliability of methods and instruments when assessing the target group. Research should also attempt to delineate along amputation levels, as they have unique diagnostic codes in ICD and unique balance and postural control features may exist. Consensus on best practice for research in this area may allow for meta-analytical studies, addressing the issues of small sample size and subsequent generalizability.

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ACKNOWLEDGEMENTS: The authors wish to acknowledge Margareta Hjort at Jönköping University for her assistance during the project's search stage.

Free Paper Session
Prosthetics: Lower Limb – Prosthetic Knees

4.2.1.a

Use of Dynamic Time Warping to Assess Bidimensional Knee Flexion Quality in Prosthetic Knee Function in Children

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BACKGROUND

Research has compared gait kinematics in young children with limb loss who receive a prosthetic knee at different stages of growth and development [1]. An “Early Knee” protocol provides children with a working knee in the first prosthesis [2], sooner than the traditional protocol. While several studies have shown that children in the Early Knee protocol utilize the prosthetic knee joint for knee flexion in walking, quantification of this flexion has thus far been limited to the maximum flexion angle.

AIM

To compare swing phase flexion to age-matched typically developing controls using Dynamic Time Warping (DTW), a technique that compares the flexion curves from both a temporal phase perspective and an overall amplitude perspective [3].

METHOD

Ten children (3 m, 7 f) participated in this IRB-approved study, five per group, aged 15-69 months. Children in the limb loss group had PFFD. Four used an Otto Bock 3R38 knee and the oldest used a Total Knee Junior. Typically developing children were age-matched. 3D gait analysis was conducted at 100 Hz while children walked at self-selected pace across a 10 m path. DTW was conducted on knee flexion results from toe-off to the end of the gait cycle. DTW produces a Warping Cost that indicates differences in timing and phase, and an RMS Difference that indicates remaining differences in flexion amplitude after the signals have been warped.

RESULTS

DTW was successfully applied to knee swing phase knee flexion data (Fig. 1). Matching cost was very low in both temporal and amplitude aspects in four of five children. Temporal warping in those four children varied from 2.26 to 3.11. RMS amplitude difference varied from 3.37° to 5.85°. The poorest match was in the 47-48 month-old pair. Warping cost was 4.10, and RMS amplitude difference was 25.23°, which was 20.6° greater than the remaining mean. There was no correlation with age.

DISCUSSION AND CONCLUSION

For most children, swing phase knee flexion with a prosthetic knee was very similar, both in timing and amplitude, to their typically developing peers, indicating effectiveness of the Early Knee prosthetic prescription protocol. The exception was the 48 m child who demonstrated longer and much smaller (peak of 40°) flexion, possibly due to that subject’s long residual limb and 25th percentile body weight. DTW is useful for assessment of knee flexion quality.

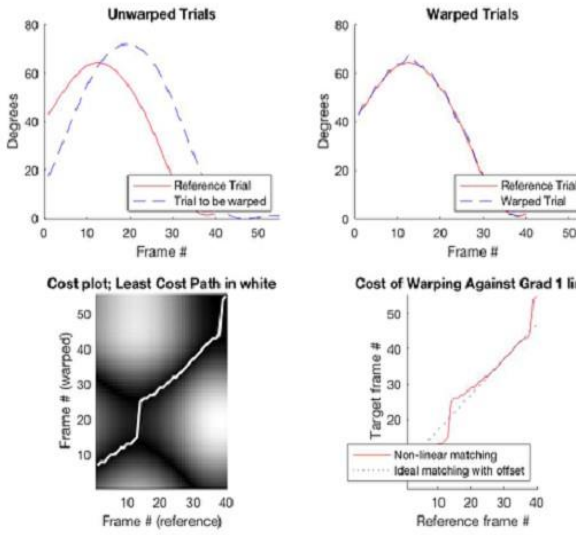

Figure 1: DTW process for one pair, with original curves on left (solid red = control, dashed blue = Early Knee) and warped curves on top right.

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ACKNOWLEDGEMENTS: Funded by Gerber Foundation Grant #1828-3236. Thanks to Sibylle Thies, U. of Salford for DTW source code.

4.2.1.b

User-Relevant Factors Impacting the Quality of Life of Lower Limb Amputees and the Overall Satisfaction with Their Prosthetic Knee

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BACKGROUND
Persons with an amputation through or above the knee are heavily reliant on an adequate set of components for their prosthesis. The choice for a certain type of knee, either mechanical or auto-adaptive, is an important decision. In order to improve the process of adjusting the specific prosthetic properties to the expectations of the prosthetic users, the development of a decision aid is of importance.

AIM
To identify which factors impact the quality of life and satisfaction with the prosthesis in adults with an amputation through or above the knee.

METHOD
A qualitative meta-synthesis was conducted by searching five databases. Studies were considered eligible if they (1) contained qualitative data about adults with an amputation through or above the knee with experience in using commercially available prostheses; (2) focused on the user's opinions. The results sections of the included studies were extracted and coded in Atlas.ti using an a-priori framework [1]. If applicable, new factors were added to this framework. Identified factors were divided into main themes and tested during a focus group with eight adults with an amputation through or above the knee. New factors that were identified during the focus group were added to create the final framework.

RESULTS
Out of 4922 articles, 23 studies were included. From these studies, 111 factors were identified and divided over 7 themes: 'prosthesis related factors'; 'rehabilitation, costs and prosthetist'; 'mental'; 'physical'; 'social'; 'activities and participation' and 'walking'. Participants of the focus group acknowledged most factors. A total of 13 factors were added to finalize the framework. The focus group illustrated that the most important factors for lower-limb prosthesis users were 'procedure health insurance', 'communication with health care providers' and 'expectations'.

DISCUSSION AND CONCLUSION
This study has illustrated which factors have the most influence on the quality of life and satisfaction of lower-limb prosthesis users. Since not all factors will be suitable for the decision aid that is currently in development, the identified factors will be analysed further and the most relevant and suitable factors will eventually form the base input for the decision aid.

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ACKNOWLEDGEMENTS: The authors want to thank Dr. S. van Twillert and E. van Veen for their help with organisation of the focus groups and ZonMW for the funding.

4.2.1.c
What a Knee Should Be: Perspectives of Highly Active Prosthetic Users

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BACKGROUND
Microprocessor-controlled knees have become available to people with transfemoral amputation in the past two decades. While associated with greater economic benefits and clinical outcomes when compared to non-microprocessor-controlled solutions, some individuals do not utilize all the functions they can provide or discontinue use altogether. Increased understanding of the relationship between human factors and prosthetic functions and their influence on peoples' experiences is needed to make microprocessor-controlled knees as well as their specific functions more accessible to their users.

AIM
We aimed to explore prosthetic experiences of highly active individuals with transfemoral amputation, identify factors important to prosthetic use, acceptance, and satisfaction as well as opportunities in advanced prosthetic development.

METHOD
We conducted semi-structured interviews with 5 highly active individuals with transfemoral amputation. Transcripts based on audio and video recordings during the interviews were later reviewed and salient themes identified. Some themes were included in the interview script while others were identified afterwards based on reoccurring ideas and words. Each data point was appointed a code. The codes were then arranged in meaningful clusters by relation based on researcher interpretation.

RESULTS
Several factors important for prosthetic use, acceptance and satisfaction were identified as well as considerations for their applicability; 1) Feeling in control of prosthesis; 2) Consistent Prosthesis; 3) Intuitive Prosthesis; 4) Feeling unrestricted by prosthesis; 5) Spontaneity; 6) Easy to walk and change speed; 7) Noise; 8) Easy to trigger and transition between modes; 9) Individually relevant modes; 10) Harmonious function with ankle; 11) Shock absorption; 12) Waterproof; 13) Appearance; 14) Weight.

DISCUSSION AND CONCLUSION
Fostering trust through consistent and intuitive functions that can be used during various activities is perceived as highly important for prosthetic satisfaction. Furthermore, expected long-term benefits associated with advanced devices are, alone, not always sufficient motivation for their use. Active assistance coupled with more intuitive triggering methods is necessary to make advanced prostheses and their functions more accessible and beneficial. Finally, individual characteristics and needs influence use and acceptance, highlighting the need for further investigation of human-machine interaction in prosthetics.

ACKNOWLEDGEMENTS: Funding was provided by The Icelandic Centre for Research (RANNIS) and Össur hf, Iceland, which further provided technical support.

4.2.1.d

The Effect of Microprocessor Controlled Exo-Prosthetic Knees on Limited Community Ambulators: Systematic Review and Meta-Analysis

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BACKGROUND

The clinical benefits of microprocessor-controlled prosthetic knees (MPK) in unlimited community ambulators are well-established. A systematic review in limited community ambulators published in 2014 found benefits in safety, function and perception in a limited number of studies [1]. In the meantime, the topic received continued scientific attention and the body of evidence increased significantly in quality and quantity.

AIM

This work provides an updated of systematic review and a meta-analysis of all published data.

METHOD

Literature search was conducted in seven scientific data bases including Medline, the Cochlear Library and Google scholar. Search terms related to MPK, transfemoral amputation, MFCL-2 and low mobility. Review was conducted by AH and AK. Rating followed the recommendations of the American Academy of Orthotics and Prosthetics. Inclusion required the studies to comprise quantitative and analysable information on low mobility subjects allowing a direct comparison to non-MPKs. Outcomes were categorized whether they favour the use of MPK, non-MPK or were inconclusive. Mean differences (MD) or standardized mean differences (SMD) were calculated with 95% CIs. Selected effect sizes for SDMs were calculated using Heges `g.

RESULTS

Literature research identified 922 items. 30 publications were reviewed in full text. Eleven studies presented in thirteen publications [2-9] were analysed. Studies covered one randomized trial, one controlled trial, seven before-after trials and two observatory trials. Seven trials were assessed of high, three of moderate and one of low quality. The literature describes 2,325 patients, 660 classified as low mobility ambulators. The meta-analysis demonstrated that MPKs in limited community ambulators led to a reduction in falls (SMD g:-0.6;95%CI[-0.91,-0.29;I^2=0%]), fear of falling (SMD g:1.13;95%CI[0.37,1.88;I^2=84%]), an improvement in mobility grade (0.55;95%CI[0.51,0.59]), in patient-reported ambulation (MD7.61;95%CI[1.82,13.29; I^2=0%]) and utility(MD7.76;95%CI[2.05-13.47;I^2=0%]). Other outcomes exhibited trends in favour of MPK use or remained insensitive, no outcome favoured non-MPKs.

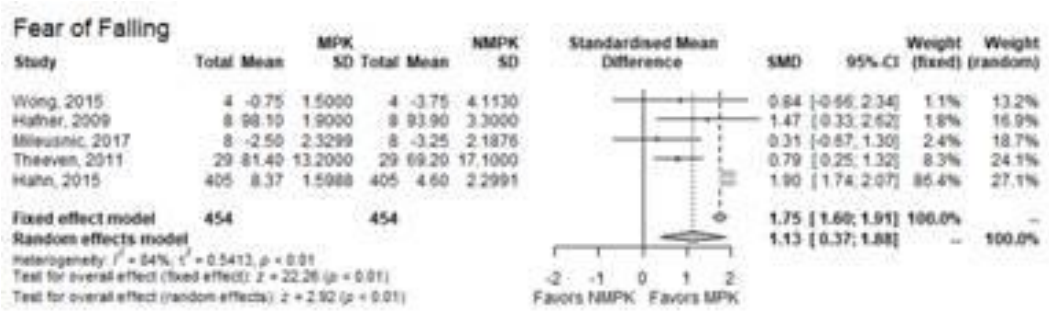

Figure 1. MPKs in low mobility ambulators lead to significant decrease in falls and fear of falling.

DISCUSSION AND CONCLUSION

Effects of MPKs in low mobility ambulators are of similar or larger magnitude than in unlimited community walkers. The results of this work suggest that MPKs should be considered a valuable therapeutic option in limited community ambulators with an above-knee amputation.

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ACKNOWLEDGEMENTS: We acknowledge depersonalized raw data being made available for analysis by Prof. Kaufmann.

4.2.1.e
The NHS England MPK Policy: Does It Provide Sustained Patient Benefits?

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BACKGROUND
Microprocessor knees (MPKs) have been shown to provide many benefits to patients [1] including significantly reducing the probability of falling [2,3]. Since December 2016, NHS England has provided funding for MPK provision [4]. However, little information has been published regarding its success. Furthermore, it is unclear whether patient benefits are sustained over time.

AIM
To investigate whether MPK provision has a sustained benefit within the NHS England amputee population.

METHOD
Data collected by clinicians, from centres in Northern England, were retrospectively analysed. The data consisted of scientifically-validated outcome measures required by, and collected in accordance with, the NHS England MPK policy guidelines.

There were no restrictions on age, mass, gender, amputation aetiology or K-level, except those defined by the policy [4]. Primary amputees and those already using an MPK were excluded from the analysis. Patient scores were collected from baseline (with respect to their previous knee), and after one and six months of MPK use. For those who had scores recorded for all three timepoints, Friedman and post-hoc Nemenyi tests were used to evaluate significant differences between the three.

RESULTS
The frequency of trips and falls, Patient Health Questionnaire (PHQ-9), Reintegration to Normal Living Index (RNLI), two minute walk test (2MWT), six minute walk test (6MWT), 10 walk test, Plus-M T score, and several PEQ domains (ambulation, appearance, frustration, and utility) all showed significant improvements with MPK use, which was sustained at six months.

Some outcomes (GAD-7, PEQ Residual limb health scale, PEQ sounds scale) showed a significant improvement after one month, compared to baseline, but no significant difference between six months and baseline.
The timed-up-and-go (TUG) test was not significantly improved after one month, but was significantly improved, compared to baseline, after six months.

Resting heart rate, socket comfort score (SCS), and some PEQ domains (perceived response, social burden and wellbeing) did not show any significant changes between timepoints.

DISCUSSION AND CONCLUSION
The results of this analysis demonstrate that many of the patient benefits provided by an MPK persist over time. More subjective measures may be affected by novelty at early assessment (e.g. PEQ sounds domain). Other, more physical tasks may take time and practice to achieve an improvement (e.g. TUG test).

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Symposium
Orthotics: Lower Limb

4.2.2
Ankle-Foot Orthoses in Early Post-Stroke Rehabilitation

Corien Nikamp[1,2], Nerrolyn Ramstrand[3], Paul Charlton[4]

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Abstract
Ankle-foot orthoses (AFOs) are often provided during stroke rehabilitation, to improve stability in stance, facilitate toe-clearance in swing phase and promote heel strike (Leung 2003). However, the timing of providing AFOs in stroke rehabilitation is a controversial topic. Some propose that AFOs should be considered as an early intervention rather than as a last resort, proposing that they help avoid the development of abnormal patterns, or prevent such patterns becoming established (NHS Best Practice Statement, 2009). Others are critical to early orthotic interventions, as studies have reported that use of an AFO reduces tibialis anterior muscle activity (Lairamore, 2011) and this disuse may lead to loss of existing strength, delays in motor relearning and prolong dependence on the device.

This symposium will explore the role of AFOs in early stroke rehabilitation. The presenters will detail current clinical practices, including AFO dosage and design, and highlight challenges from a patient, orthotist and interdisciplinary team perspective. Current knowledge related to patient outcomes associated with early AFO provision will then be presented by exploring a wide range of biomechanical, physiological and psychosocial variables and how these may be affected, negatively or positively, through provision of AFOs during the early phases of stroke rehabilitation. Where research evidence is limited regarding specific outcome variables, the presenters will draw upon theoretical models to hypothesize on potential effects of AFOs as well as expected relationships between different variables. Finally, the presenters will summarize the current state of knowledge, discuss clinical implications and identify needs for future research.

Statement of the learning objectives
The objective of the symposium is to learn about the role of AFOs in early stroke rehabilitation by reviewing current practices, scientific evidence and theoretical models.

Advanced Instructional Course
Rehabilitation Medicine and Surgery

4.2.3

Starting and Managing an Osseointegration Surgical and Rehabilitation Program for Lower Limb Amputees. How I do it.

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Abstract

Starting and managing a successful surgical and rehabilitation program in your own centre is a challenge. It may happen that your rehabilitation colleague will ask you to cover the surgical part of osseointegration treatments for individuals with difficult amputation stumps that are not suitable for socket suspension. The focus of this instructional course will be every step of this interesting process. From the first step of testing feasibility by performing market research and exploring various compensation systems to training a surgical team with appropriate implant systems, recruitment of potential candidates until decisions about post-operative clinical follow-up with research data management. Orthopaedic surgeons from various parts of the globe will share their experience with the intention to discuss possibilities in your own country.

Statement of the learning objectives

This instructional course invites ambitious colleagues to learn about starting and managing a successful surgical and rehabilitation osseointegration program in your own country from a Dutch, American, Canadian and Indian point of view.

Advanced Instructional Course
Prosthetics: Lower Limb

4.3.1
Challenges of a Modern Transfemoral Socket Design

Marlo Ortiz[1], Michael Schäfer[2], Malte Bellmann[3], Jason Kahle[4]

[1]Ortiz Internacional SA de CV, Guadalajara, Mexico. [2]Pohlig GmbH, Traunstein, Germany. [3]Otto Bock, Duderstadt, Germany. [4]OP Solutions, Tampa, USA

Abstract
The prosthetic socket technologies after above knee amputation is currently experiencing many innovative care approaches around the world that raise questions and make even experienced providers think about.

What are minimum and adequate requirements for the different stump lengths, properties of muscle and soft-tissue-imbedding techniques?

It is undisputed that the performance of the amputees depends significantly on the design of the prosthetic socket.

As the central link between man and technology, it has to fulfil biomechanical aspects as well as specific imbedding characteristics.

Some of them can be discussed, others are almost irrefutable, since they are based on clearly comprehensible physical laws.

Experts in this care area report on the latest approaches to high performance socket designs in transfemoral prosthetics. Different methods of shape detection from plaster cast to digital scan are considered as well as the critical debate on the design of the socket's entry level (Ischial containment, Ischio-Ramal containment, sub-ischial technique).

At the same time, concrete approaches for the improvement of the socket's guidance behaviour will be shown, as well as measures with influence on the reduction of stump - socket - pseudarthrosis and the painful stump.

Statement of the learning objectives
A report on the latest approaches to high performance socket designs in transfemoral prosthetics as well as the critical debate on the design of the socket's entry level (Ischial containment, Ischio-Ramal containment, subischial technique).

Free Paper Session
Gait and Balance: Gait over Different Terrains

4.3.2.a
Effects of Cross-Slopes on the Gait of Persons with a Transtibial Amputation

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BACKGROUND
For persons with a lower leg amputation (PwA), walking on uneven ground require compensatory movement strategies, partly caused by limited adaptability of prosthetic components. Walking on cross-slopes, a form of uneven ground, is a situation active PwA face regularly. However, only few studies investigated cross-slope walking of PwA [1-3], and the one that studied adaptations focused on the swing phase on the prosthetic side [3].

AIM
To investigate in more detail the effects of cross-slopes on gait characteristics (in stance and swing phase) of persons with a transtibial amputation (TTA) and compare it with level walking.

METHOD
12 TTA were provided with energy-storage and return feet (ESR) for the time of the study. Level walking and cross-slope walking on 5° and 10° tilted tracks were investigated in a gait lab. Kinematic data were recorded with a Vicon system. A Kistler force plate was embedded in the track to measure the ground reaction forces (GRF). Spatio-temporal and biomechanical parameters (GRF, sagittal ankle and knee angles, pelvis inclination and upper body tilt) were analysed with respect to situation and side. A repeated measurement ANOVA with post-hoc tests were used to show possible differences to level walking.

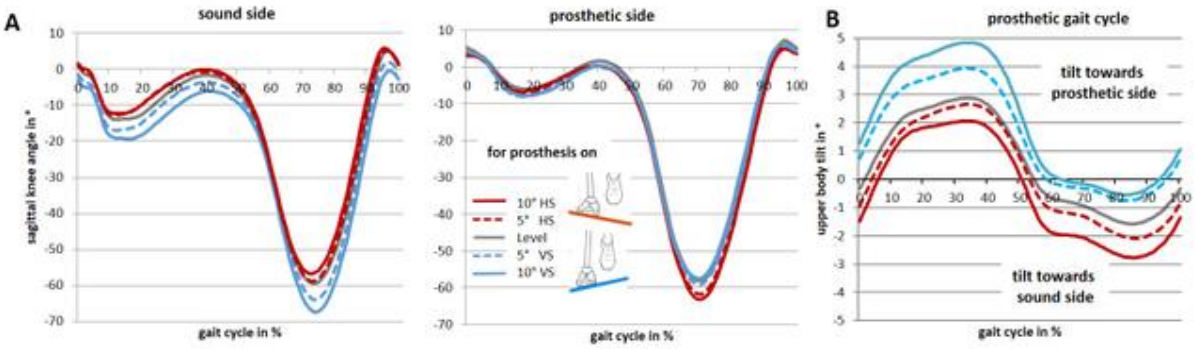

Figure 1: Sagittal knee angle and upper body tilt.

RESULTS
Spatio-temporal gait characteristics and GRF showed known differences between prosthetic and sound side but revealed only minor adaptations for the different cross-slope situations. Significant adaptations to the different situations were observed in the sagittal knee and ankle angles, in the pelvis inclination and upper body tilt compared to the level situation. The sagittal ankle angle of the sound side showed a reduced range of motion for Valleyside and an increased one for Hillside while the prosthetic side was unaffected. For the sagittal knee angle, adaptations were observed for the sound and the prosthetic side, figure 1A, which adapt the functional leg length. Pelvis inclination and upper body tilt showed similar adaptations to the cross-slope tilt, figure 1B, which are likely compensation and/or stabilization mechanisms of the upper body.

DISCUSSION AND CONCLUSION
Adaptations to the cross-slopes were observed for the prosthetic and sound side in some parameters. Its effect size increased with increasing cross-slope tilt. The results confirm and extend findings of previous studies [3]. However, most observed effects had the same order of magnitude or were smaller compared to general adaptation effects in gait of TTA if compared to controls.

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4.3.2.b

Prolonged Use of a Sensory Neuroprosthesis Affects Performance and Strategy in Negotiating Stairs

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BACKGROUND

Somatosensory feedback is compromised following a limb amputation. Due to this deficit, lower-limb amputees rely heavily on compensatory mechanisms, such as increased reliance on visual feedback, to maintain balance[1]. Our team has developed a sensory neuroprosthesis (SNP) which provides direct sensory feedback to the user based on how the prosthesis interacts with the environment. In this work, we present effects of prolonged home use of the SNP on stair negotiation.

AIM

Determine if prolonged use of a SNP at home and in the community could improve performance and alter the compensatory strategy typically utilized by a below-knee amputee to negotiate stairs.

METHOD

A transtibial amputee with implanted stimulating electrodes used a SNP which provided sensation corresponding to the pressure applied to the plantar surface of the prosthetic foot elicited by electrically stimulating the peripheral nerves in the residual limb[2]. The participant used the device at home for 291 days and visited the laboratory six times to perform a stair assessment. The task involved negotiating the 4” and 8” stairs while carrying or not carrying a tray to limit visual feedback. SNP activated and deactivated conditions were tested with performance order randomized. Error frequency and strategy were then identified through video analysis.

RESULTS

Three stair negotiation strategies were identified: lead foot preference, foot orientation on step, and stomping. We also identified 10 categories of errors while performing the task which allowed us to quantify any changes in the performance. Stair height, direction of movement (ascent or descent), SNP mode (activated or deactivated), and tray use influenced strategy selection, error frequency, and type of errors committed. Although tread depth was uniform, more errors occurred during 4” stair ascent than any other condition. Each trial was timed, but timing could not differentiate between strategies selected or SNP mode to determine how well the task was performed. With prolonged home use of the SNP, the subject began to adjust his self-selected compensatory strategies to a more normalized pattern.

DISCUSSION AND CONCLUSION

Lack of somatosensation causes lower-limb amputees to employ compensatory mechanisms to safely negotiate stairs. To study how a SNP can influence this task, we systematically characterized stair performance by identifying strategy and error, monitoring changes over time, and quantifying safety through correlation with error frequency. Our findings suggest that prolonged use of the SNP led to adoption of a more normalized biomechanical approach to stairs and reduction in error frequency.

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4.3.2.c

Obstacle Crossing in Individuals with Unilateral Transfemoral Amputation: The Influence of Ankle-Foot and Knee Components

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BACKGROUND

Being able to negotiate environmental hazards, such as obstacles on the floor, is important for avoiding the occurrence of a trip or fall and subsequent injury. Previous research has reported on how individuals with both transtibial and transfemoral amputations cross obstacles [1-3]. Information regarding obstacle crossing strategy, lead limb preferences, lower limb joint kinematics and kinetics have been highlighted [1-3]. However, it is not clear how different prosthetic components may influence obstacle crossing behaviour.

AIM

To investigate how varying both ankle-foot and knee componentry, in individuals with unilateral transfemoral amputation, influenced their ability to cross an environmental obstacle.

METHOD

Eight participants (54.8±12.4; 1.8±0.05m; 84.8±13kg; prosthetic experience 24.5±15.91 years) with unilateral transfemoral amputation, crossed an obstacle (0.04x0.08 m; depth*height) placed along a flat walkway, freely choosing their obstacle crossing strategy. Participants used four different combinations of prosthetic componentry; either a microprocessor-controlled (MPK, Orion3) or non-microprocessor-controlled (NMPK) knee component with either a hydraulically articulating (HYD, Echelon) or rigid (RIG, Esprit) ankle-foot component (all Blatchford, Basingstoke, UK). Reflective markers were placed on the lower limbs, with a 13-camera motion capture system (Qualisys AB, Gothenburg, SE) capturing kinematics at 100Hz. Lead limb preference, approach velocity and lead limb vertical toe clearance and final foot placement where recorded.

RESULTS

Self-selected lead limb preferences were unaffected by prosthetic component combination. Only 2/8 participants deviated once (1/4 conditions) from their 'usual' lead limb. Approach velocity was highest with the MPK+HYD combination ($F(3,18) = 4.16$, $p = 0.021$, $\eta p^2 = 0.41$). Final foot placement seemed unaffected by prosthetic combination. Although not analysed statistically, vertical toe clearance was lower and varied more by prosthetic combination when leading with the intact vs. prosthetic limb.

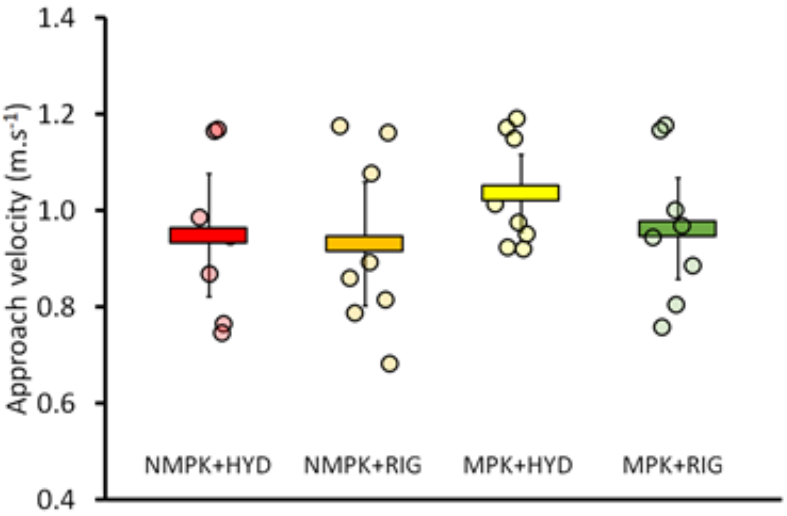

Figure 1. Combined limb approach velocity for all combinations of prosthetic componentry.

DISCUSSION AND CONCLUSION

Regardless of prosthetic component combination, all participants were able to cross the obstacle safely, avoiding trips and falls. In addition, a variety of lead limb preference strategies were observed. This may reflect the relatively high level of function (all K3) and neuromotor flexibility of participants in the study sample. Approach velocity was higher in the MPK+HYD combination, potentially suggesting that obstacle crossing with more functionally advanced prosthetic components could be advantageous, when constraints are placed on task completion time.

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4.3.2.d

The Effect of Simulated Visual Impairment on Obstacle Crossing in Individuals with Unilateral Transtibial Amputation

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BACKGROUND

Performing everyday tasks requires accurate foot placement, adequate vision and proprioception [1]. Simulating visual impairment reduces the ability to accurately perceive the characteristics of a raised surface placed within the travel path [2]. Unilateral transtibial limb loss leads to less accurate and precise intact limb foot placement, potentially due to altered proprioceptive feedback [3]. Exploring how impaired vision combined with reduced proprioception, affects obstacle crossing, may contribute to understanding balance and fall-related problems reported in people with limb loss.

AIM

To explore the effects of simulated visual impairment on obstacle crossing behaviour in individuals with unilateral transtibial amputation (IUTA).

METHOD

Seven male IUTAs (38±13 years, 1.83m, 92.5kg, all K3) walked along a 10m walkway crossing an obstacle (two conditions: FLAT = 10mm(H) x 600mm(W) x 100mm(D), TALL = 100mm(H) x 600mm(W) x 10mm(D)) with (blurred glasses, BLUR) and without (clear glasses, CLEAR) simulated visual impairment. Visual acuity and contrast sensitivity were measured in each condition. Full-body kinematics were recorded as participants approached and crossed the obstacle, leading with either the INTACT or PROSTHETIC limb. A three-way repeated measure ANOVA compared differences between limb, obstacle and visual impairment for: lead limb vertical toe clearance (VTC), final foot placement (FFP), and approach velocity.

RESULTS

Visual acuity (Z=2.2, p=0.028) and contrast sensitivity (t(6)=6.24, p<0.001) reduced in the BLUR vs. CLEAR conditions. PROTHETIC limb VTC increased over the FLAT obstacle (+6mm) but reduced over the TALL obstacle (-13mm) compared to the intact limb (F(1,6)=7.57, p=0.03, ηp^2=0.56). Lead limb VTC increased for BLUR (115mm) vs. CLEAR (95mm), with this difference being greater in the TALL (+27mm) vs. FLAT (+12mm) obstacle conditions (F(1,6)=42.6, p<0.001, ηp^2=0.88). Final foot placement was further away from the obstacle in both the BLUR (207mm vs 165mm) (F(1,6)=19.71, p=0.004, ηp^2=0.77) and TALL (202mm vs. 170mm) (F(1,6)=9.732, p=0.021, ηp^2=0.62) conditions. Approach velocity reduced when crossing the TALL (1.2m.s-1) vs. FLAT (1.1m.s-1) obstacle (F(1,5)=53.62, p<0.001, ηp^2=0.92).

DISCUSSION AND CONCLUSION

Reduced approach velocity and increased final foot placement when crossing the TALL obstacle suggested that IUTAs perceived the heightened risk of this environmental obstacle. However, VTC was reduced in the PROSTHETIC limb when crossing a TALL obstacle, pointing to an inability to mitigate this risk, potentially increasing the risk of tripping. The increased VTC in the BLUR compared to CLEAR condition over the TALL obstacle also suggests participants acted more cautiously, which may be due to increased task complexity/risk.

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4.3.2.e

Locomotor Response of Upper Limb Prosthesis Users to a Simulated Trip: A Pilot Study

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BACKGROUND

Almost half of persons with major upper limb loss (ULL) fall at least once per year and nearly one third of reported most recent falls result in injury (1). In persons with ULL, the likelihood of falling two or more times in a year increases sixfold with the reported use of an upper limb prosthesis (ULP) (1). These findings, and additional biomechanical studies (2,3), suggest that persons with ULL may experience impaired postural control and locomotor stability.

AIM

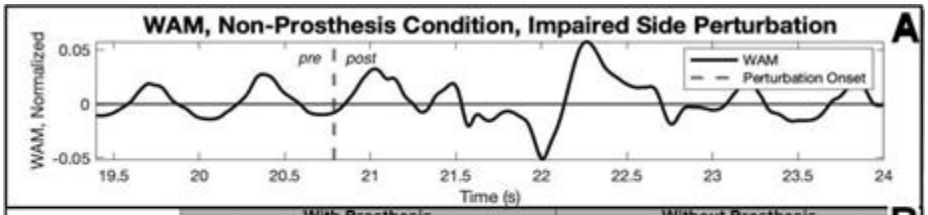
To characterize the locomotor response of persons with ULL to a simulated trip and assess effects of prosthesis use on that response.

METHOD

A participant completed two tasks walking on a treadmill (Motek, the Netherlands) wearing a safety harness: 1) baseline walking at 1.0 m/s and self-selected speed, and 2) 12 perturbation trials. Tasks were completed twice: with and without their prosthesis. Perturbation trials consisted of steady-state walking at 1.0 m/s that was unexpectedly interrupted by a rapid treadmill acceleration-deceleration during single limb support on either the sound or impaired side (6 each side). Kinematics were collected with an optical motion capture system (Motion Analysis, CA). Sagittal-plane whole-body angular momentum (WAM), trunk inclination (TI), and trunk inclination velocity (TV) pre- and post-perturbation were estimated using a biomechanical model (Visual3D, C-Motion, MD).

RESULTS

One male participant (58 yrs, 178.0 cm, 95.8 kg, myoelectric prosthesis user) recovered from all perturbation trials without a fall. Instantaneous normalized WAM for one representative perturbation trial is shown in Fig. 1A. Average values for maximum TI, maximum TV and WAM range pre- and post-perturbation across five trials (removing the first from both limb sides) are shown in Fig. 1B. The perturbation successfully generated a forward trunk as reflected by increased TI, TV and WAM. While TI and TV were near equivalent for all conditions, WAM range was considerably higher when the participant did not use their prosthesis to suggest greater postural control demands, and this elevation was greatest when the perturbation was delivered during the sound side single support indicating an asymmetric response.



B

		With Prosthesis		Without Prosthesis	
		Sound Side Perturbation	Impaired Side Perturbation	Sound Side Perturbation	Impaired Side Perturbation
TI (°)	*pre*	13.8±0.6	13.7±0.8	13.6±0.4	13.5±0.3
	post	17.7±1.3	17.3±0.7	17.0±1.6	15.7±1.2
TV (°/s)	*pre*	22.5±1.3	22.2±1.4	23.8±0.7	23.6±0.7
	post	40.0±6.6	31.3±3.3	41.8±10.1	35.0±11.0
WAM (norm.)	*pre*	0.045±0.001	0.036±0.021	0.047±0.001	0.045±0.001
	post	0.067±0.006	0.065±0.008	0.089±0.012	0.078±0.020

Figure 1: (**A**) Instantaneous WAM in the sagittal plane (normalized by body mass, height and walking speed); (**B**) Maximum TI, maximum TV and WAM range (mean±SD) separated by prosthesis condition and perturbation

DISCUSSION AND CONCLUSION

The increase in TI, TV and WAM post-perturbation indicates that the participant experienced a disturbance to walking behaviour from the simulated trip. Importantly, WAM range was greatest post-perturbation when disturbed during sound side single limb support and the participant did not wear his prosthesis. These findings suggest an asymmetric locomotor response following a trip that may share an interaction with ULP wear and could help better understand mechanisms underlying fall risk in this patient group. Data collection is ongoing.

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Free Paper Session
Rehabilitation Medicine and Surgery: Upper Limb

4.3.3.a
Effectiveness of Hand Splints in Rheumatoid Arthritis: A Systematic Review of Randomized Controlled Trials

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BACKGROUND
Management of established Rheumatoid Arthritis aims to control pain, inflammation and prevent joint damage and deformity. Hand splints may be seldom recommended to reduce pain, improve hand function and avoid further joint deterioration. However, the prescription of orthosis has been shadowed by a lack of rigorous study methodology. Only one previous Cochrane work in 2001 [1] studied the effectiveness of orthosis in Rheumatoid Arthritis and reached no definitive conclusions.

AIM
To perform a systematic review on the effectiveness of splints in the management of the rheumatoid hand.

METHOD
A comprehensive search of the available literature was performed using electronic databases (MEDLINE, PEDro and CENTRAL) up to February 2021. Keywords relevant to the question being studied were chosen. All randomized controlled trials (RCT) comparing the use of splints against other interventions were retrieved for further analysis. References of selected studies were further analysed for inclusion of any missing studies. Quality of evidence was assessed using the Pedro scale. Findings were summarized and interpreted using a narrative approach.

RESULTS
Fourteen randomized controlled trials were retrieved. The quality of evidence among studies was fair with a mean PEDro score of 5.5. The most common primary outcomes assessed were pain, grip strength, dexterity, and function. Among the four studies scoring between good and high quality, one showed no significant differences in outcomes, while the others demonstrated significant positive results in one or more of these outcomes. One high-quality study and one fair-quality study demonstrated a reduction of pain on boutonniere deformity and an improvement of dexterity and pain in swan neck deformities, respectively. In the lower quality study group evidence was also conflicting although favoring modest benefits of hand splints.

DISCUSSION AND CONCLUSION
In general, research seems to favor a modest positive benefit of splints on pain scores and handgrip strength, while the results on dexterity and function are still scarce. The current body of evidence is still insufficient to draw definitive recommendations on this subject, owing to the heterogeneity of the available studies and the impossibility of data pooling for meta-analysis. Currently prescription of hand splints requires an individual assessment of the rheumatoid patient and its personal preferences.

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4.3.3.b
Complex Rehabilitation Model for Children, Requiring Upper Limbs Prosthetics

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BACKGROUND
Obviously, modern prostheses are not yet able to completely replace the lost limb. This happens for various reasons - the complexity of control, the lack of tactile feedback, methods of fixing the device, and design features [1]. Therefore to provide a permanent and confident use of the device training before and after prosthetic fitting is highly recommended [2]. Also the exact amount of rehabilitation and effectiveness of distant interaction with the family still remains unclear.

AIM
This research aims to evaluate the effectiveness of a 3 step inpatient and distant rehabilitation training program applied before and after the prosthesis fitting.

METHOD
72 body-powered prothesis were fitted for children 2-17 years old. The general group was divided into 2 subgroups. Subgroup1 received complex rehabilitation and training program, while subgroup2 did not receive any rehabilitation or training. The program for subgroup1 consisted of 3 steps. Step1 included outpatient training with the help of age specific written material, aimed to physically and psychologically prepare the child and the family for the device installation. Step2 took place right after prosthesis fitting and included intensive 1-day inpatient rehabilitation with the help of physiotherapist, occupational therapist and clinical psychologist. Step3 included distant care, aimed to provide information needed to solve problems and improve skills and motivation.

RESULTS
The results of 2 subgroups were evaluated 1 year after prosthesis fitting through the parents survey form. Subgroup 1 had more permanent pattern of the device usage:
- 67% of children wore the device on the daily basis or at least 4 times per week compared to 50% in subgroup 2
- 33% was able to wear the device for over 5 hours per day compared to 11% in subgroup 2
- 75% used the device in the kindergarten compared to 39% in subgroup 2

Also parents from group 1 were more involved into home rehabilitation while children showed more initiative in device usage. In terms of time needed for daily routines and active grasp usage there was no statistically significant difference between 2 subgroups

DISCUSSION AND CONCLUSION
A interdisciplinary 3 step rehabilitation and training program with both inpatient and distant components allowed to improve the pattern and the duration of the device usage. After the program both children and parents showed more involvement into home training and rehabilitation processes. However further investigation on the bigger group is planned to prove the differences.

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4.3.3.c

Dutch Adults with Major Congenital Upper Limb Differences; Their Musculoskeletal Complaints and (Dis)ability

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BACKGROUND
A missing, incomplete or dysplastic *hand* or arm at birth is referred to as *congenital upper limb anomaly, -deficiency* or –difference. These congenital upper limb differences (CoULD) are rare, with a prevalence ranging between 10-30/10.000. Severity of CoULD can range from relatively minor differences such as clinodactyly to major transversal or longitudinal deficiencies, such as a cleft hand. Since almost every daily activity requires a form of hand function, CoULD can impact functioning considerably.

AIM
Determine the prevalence of musculoskeletal complaints (MSCs) in adults with major congenital upper limb differences (CoULD) compared to able-bodied controls, and to examine associations of MSCs and disability with various biopsychosocial factors.

METHOD
Questionnaire-based cross-sectional study assessing prevalence of MSCs, disability, general and mental health status, physical work demands, and upper extremity range of motion.

RESULTS
71 persons with CoULD (participation-rate: 41%) and 71 controls were included (49% female, mean age 28.9y). Year prevalence of MSCs was significantly higher in the CoULD group (35%) than in the matched control group (18%); odds ratio 1.8. The CoULD group was less often employed and had lower scores on all measures of upper limb range of motion and hand grip. With regression analysis MSCs were associated with higher upper limb related disability measured with the DASH and higher reported work demands. Disability was associated with female gender, more joints with limited range of motion, unemployment and lower general and mental health. Factors associated with disability did not differ between the groups.

DISCUSSION AND CONCLUSION
MSCs area frequent problem in young adults with major CoULD. To prevent or reduce MSC and disability, clinicians and researchers should be aware of the associated factors.

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4.3.3.d

Associated Factors for Musculoskeletal Complaints in Individuals with Upper Limb Absence – Focus Group Results and a Scoping Review

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BACKGROUND

Musculoskeletal complaints (MSCs) are highly prevalent in individuals with upper limb absence (ULA)[1]. Studies have been conducted to better understand the factors associated with the development and persistence of MSCs, and show relations with repetitive movements, awkward postures, and sustained force[2,3]. However, these are mainly investigated in the two-handed population and the perspectives of individuals with ULA are not considered.

AIM

To identify facilitators and barriers for MSCs in individuals with ULA and to create an overview with all factors derived from a focus group and a scoping review.

METHOD

A focus group was held during which open questions addressing MSCs and possible risk factors were asked. An overview was created with the domains from the ICF model as main categories. Two reviewers coded the transcript with the Atlas.ti software. A scoping review was performed by searching six databases (PubMed, Web of Science, CINAHL, Cochrane Library, PsycINFO, and EMBASE). Two reviewers screened the articles and the included articles were coded with the overview from the focus group as a reference.

RESULTS

Eleven participants contributed to the focus group, of which three experienced no MSCs and eight had MSCs in the previous year. Eight studies were included in the scoping review. The total overview consisted of four domains of the ICF model including 61 factors. The participants of the focus group mainly reported psychosocial factors of the domain ‘personal factors’ and biomechanical factors of the domain ‘activities and participation’. For example, participants felt that they had to give at least 150% in all of their activities, in order to live up to their own expectations or the expectations of the environment. Additionally, the scoping review mostly resulted in prosthesis-related factors, which are categorized in the domain ‘environmental factors’, and factors within the domain ‘activities and participation’. Frequently mentioned as a cause of MSCs, although never statistically examined, were compensatory movements.

DISCUSSION AND CONCLUSION

This study identified 61 factors that are associated with MSCs in individuals with ULA. It highlights the importance of psychosocial factors, as they are deemed important by individuals with ULA, but underexposed in the literature. Furthermore, future research should focus on factors with a low level of evidence, such as compensatory movements. The overview created in this study can help in the better understanding of MSCs and ultimately in better prevention and treatment of MSCs in individuals with ULA.

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4.3.3.e

Pain Conditions in Persons with Upper Limb Amputation: New Findings from the U.S. Department of Veterans Affairs

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BACKGROUND
Painful conditions following upper limb amputation (ULA) are common and have the potential to influence prosthesis use, functional independence, and quality of life. Although residual limb and phantom limb pain (PLP) have been the most studied conditions following upper limb amputation, painful musculoskeletal conditions involving the non-amputated limb also need to be considered.

AIM
Provide information about the prevalence of post-amputation pain conditions, the factors associated with their occurrence, and the relationship of these conditions to disability and health-related quality of life (HRQOL).

METHOD
Several cross-sectional, non-interventional studies of participants with major ULA were conducted in the U.S. Department of Veterans Affairs. The first study, a telephone survey assessed demographics, amputation history, prosthesis use, function, pain, quality of life, and prosthesis satisfaction. Data was used to describe the prevalence and intensity of painful conditions and identify factors associated with PLP. A second study using in-person assessments included prosthesis evaluation, administration of self-report and functional performance measures. Data from the in-person study was used to identify factors associated with contralateral and ipsilateral shoulder pain.

RESULTS
Prevalence of PLP in 776 participants with unilateral ULA from the survey study was 73%, mean intensity score of 4.2 (SD 3.4). Amputation at the shoulder [OR 3.78 (1.93, 7.39)], amputation at the transhumeral level [OR 1.76 (1.10,2.81)], and amputation due to cancer [OR 5.33 (1.15, 24.81)] were associated with any PLP. Moderate (β=1.34, p=<0.0001) and severe (β=3.31, p<0.0001) residual limb pain intensity was associated with higher PLP intensity. Prevalence of any shoulder pain in the 107 participants from the in-person study was 30%. Prevalence of shoulder pain was greater in those using a body-powered prosthesis. Each additional year since amputation was associated with an increased likelihood of having contralateral shoulder pain (OR: 1.05, CI: 1.01, 1.10). Pain in the non-amputated limb was common (72%), averaged in the moderate intensity range, and was associated with reduced HRQOL and disability.

DISCUSSION AND CONCLUSION
Our studies involving Veterans with major ULA highlight the long-term persistence of moderate intensity PLP as well as the high prevalence of other painful conditions. Amongst prosthesis users, the shoulder contralateral to the amputation was at greatest risk, with risk increasing with every year since amputation. Recognition and management of these conditions is important because they are frequently associated with functional and quality of life implications.

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Free Paper Session
Prosthetics: Lower Limb – Sockets 2

4.4.1.a
Effects of Vacuum-Assisted Socket Suspension Systems on Prosthesis User Function: A Systematic Review

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BACKGROUND
Prosthetic sockets are a key component in connecting the user's body with the prosthesis [1]. The socket fit is critical for enabling prosthesis users to effectively complete activities of daily living. Normal fluctuations in residual limb volume often affect the fit between the residual limb and the prosthetic socket [2]. Vacuum-assisted socket suspension (VASS) technology, also known as elevated vacuum, is a form of socket suspension commonly used by prosthesis users to maintain this fit [3].

AIM
The purpose of this study was to conduct a systematic review to evaluate the current body of evidence on elevated vacuum functional impacts and proven clinical benefits.

METHOD
Database searches were conducted to locate published evidence regarding VASS: MEDLINE via PubMed, Scopus, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Web of Science. Keywords and subject headings (when available) for elevated vacuum and persons with limb loss were utilized to identify literature addressing vacuum-assisted socket system technology in prosthesis users. Resulting references were screened in two stages: (1) eliminate duplicates and (2) determine articles that met inclusion/exclusion criteria. Two raters independently completed stage 2 screening to verify inclusion/exclusion and for classification as Pertinent, Not Pertinent, or Uncertain. Discrepancies on any article classifications were resolved by discussion between the two raters.

RESULTS
The search yielded 2,366 manuscripts. Stage 1 screening identified and removed 632 duplicate records. The remaining 1,734 records were reviewed in Stage 2 screening. Stage 2 screening eliminated an additional 1,670 articles, resulting in 64 articles meeting eligibility criteria. An additional 2 eligible studies familiar to the team were subsequently added, resulting in 66 articles included in this review. Data in each article were extracted for categorization and analysis. The studies also underwent examination for quality of research. The complete results of the systematic review will be presented.

DISCUSSION AND CONCLUSION
The systematic review presents the latest evidence regarding VASS technology and its impact on prosthesis user function. VASS research has indicated benefits for prosthetic socket fit, residual limb volume management, and outcomes as compared to other suspension systems. The evidence collected in the systematic review serves as the foundation for clinical practice guidelines and evidence tables to support clinical care.

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ACKNOWLEDGEMENTS: The work was supported by an AOPA Research Award administered by the Center for Orthotic and Prosthetic Learning.

4.4.1.b

Comparative Effectiveness Trial of NU-FlexSIV and Ischial Containment Sockets

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BACKGROUND

Sub-ischial sockets have been suggested as a more comfortable alternative to Ischial Containment (IC) Sockets for people with transfemoral amputation due to the lower proximal trim lines [1-4]. However, it is unclear if removing the ischial containment might reduce function due to compromised coronal plane stability or improve function due to increased hip range of motion.

AIM

To compare comfort and functional performance of the Northwestern University Flexible Sub-Ischial Vacuum (NU-FlexSIV) Socket to the IC Socket in persons with unilateral transfemoral amputation.

METHOD

Two custom sockets (IC; NU-FlexSIV) worn in random-order full-time for 7 weeks. Testing at 1, 4 and 7 weeks. Primary outcome: change in Socket Comfort Score (SCS) at 7 weeks. Secondary outcomes: Orthotic and Prosthetic Users' Survey (OPUS) to assess lower-extremity functional status, health-related quality-of-life, and satisfaction with device, also 3D-gait analysis at multiple speeds, 5-Times Rapid Sit-to-Stand Test, Four Square Step Test, and T-Test of Agility to assess functional performance. Gait variables related to hip motion and coronal plane stability assessed. Two analysis approaches used: paired t-tests at week 7 and linear mixed-effect models (LMM, main and interaction effects of socket and time considered using data from all weeks).

RESULTS

30 participants enrolled, 25 completed with full (n=18) or partial data (n=7). 19/25 males, mean age: 45.9±13.7years, mean height: 177.2±11.6cm, and mean mass: 88.6±19.7kg. 23/25 had amputation due to non-vascular issues. All had K3/K4 mobility levels. At 7 weeks (n=19), mean SCS for IC (7.0±1.7) and NU-FlexSIV (8.4±1.1) were significantly different ($p<0.001$, 95%CI = 0.8, 2.3). Similarly, LMMs (n=25) indicated SCS was 1.7 (SE=0.45) points higher for NU-FlexSIV ($p<0.001$). Among other outcomes, only OPUS satisfaction was significantly better in NU-FlexSIV using LMM (n=25). No differences at 7 weeks in gait variables between sockets at normal speed (n=19). However, using LMMs (n=25) there was a significant main effect of socket: prosthetic-side sagittal plane hip motion significantly greater for NU-FlexSIV at all speeds. No differences in lateral trunk flexion or step width for any speed for either analysis.

DISCUSSION AND CONCLUSION

The results suggest that, after 7 weeks accommodation, the NU-FlexSIV Socket was more comfortable and led to greater satisfaction with device than the IC Socket in persons with non-vascular unilateral transfemoral amputation and K3/K4 mobility. Other patient-reported outcomes and function were no different between sockets. The NU-FlexSIV Socket did not alter gait biomechanics related to hip motion and coronal plane socket stability.

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4.4.1.c

Transfemoral Socket Fabrication Method Using Direct Casting: Outcomes Regarding Patient Satisfaction with Device and Services

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BACKGROUND

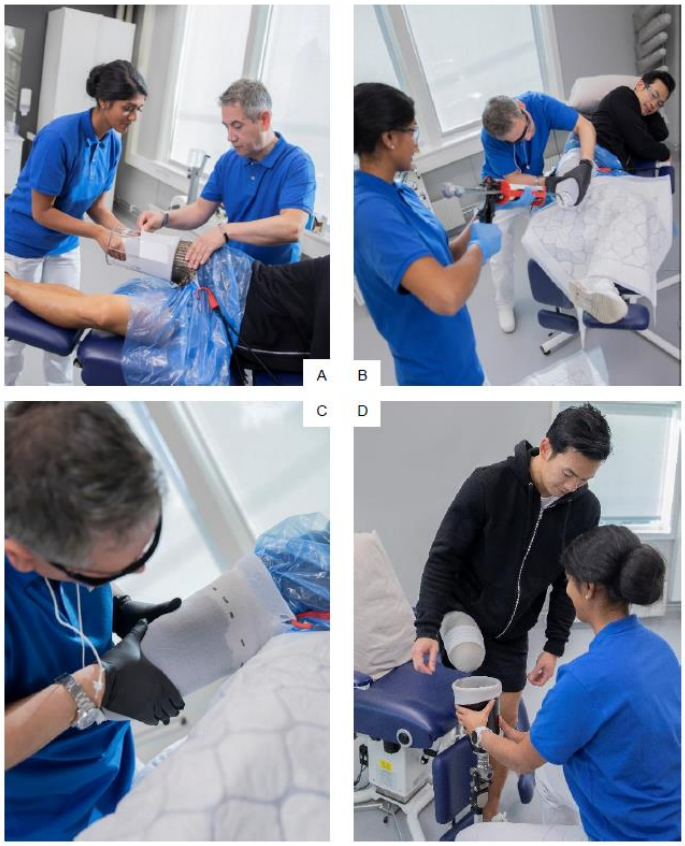
Direct Socket for transfemoral (DS-TF) prosthetic user is a novel method of fabricating a laminated interface on to the residual limb but requires different training, production method and service model than what most prosthetists are familiar with. This method and model may improve patient satisfaction by enabling interface fabrication and delivery in one visit.

AIM

Document patient satisfaction regarding DS-TF interface versus the prosthetic users' previous socket in terms of interface function and the clinic service model.

METHOD

In this longitudinal study (from July 2018 to April 2020), the DS-TF was implemented in six prosthetic clinics across the United States. Certified prosthetists (CP) and assistants were trained using a standard protocol. 47 prosthetic users participated, both those in need of a new socket and those without need. Two modules from the Orthotics and Prosthetics Users' Survey (OPUS), involving questions related to satisfaction with the Device and Services, was used to evaluate each DS-TF user outcome vs. baseline. The only part of the prosthesis that was replaced was the interface, except in 2 cases.



RESULTS

Each DS-TF interface was fabricated, fit and delivered in a single clinic visit. At 6-months follow-up, 38 users reported an average of 29.8% increase in satisfaction with their new interface compared with original, and a 14.8% increase in satisfaction with the services they received from the clinic in providing of the new prosthesis vs. their original prosthesis. The main outcome increases were between baseline (initial fitting) and 6-week follow-up and remained consistent after 6 months. This improvement was consistent irrespective if the user needed a new socket for clinical reasons or not.

DISCUSSION AND CONCLUSION

OPUS CSD questions related to the function of the interface for all subjects indicate a significant improvement in user satisfaction with their DS-TF interface over their previous interface. All improvements were consistent between the 6-week and 6-month study periods. At 6MFU the average CSS score was 93, or 14.8% higher, a significant improvement. Study shows that after standardized training and implementation, the DS-TF fabrication process including a new interface improves the user's satisfaction with their prosthetic device and services.

ACKNOWLEDGEMENTS: Study financially supported by Össur, authors are employees of Össur except I. Atlason. Principle Investigators received no compensation from Össur.

4.4.1.d
Clinical Evidence for Transfemoral Prosthetic Socket Prescription: A Review of the Literature

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BACKGROUND
The prosthetic socket is the interface which connects the human body to the artificial limb and allows transmission of body weight and forces during gait.

AIM
The review purpose is to assess the quality of scientific evidence and compare this for a variety of available TF socket designs. Comparisons will be made of socket biomechanics, metabolic efficiency and comfort and the advantages/disadvantages associated with each design.

METHOD
Socket designs included were: Quadrilateral; Ischial Containment; Marlo Anatomical Socket; Sub-Ischial; High-Fidelity and the Socket-less socket. A literature review was conducted in five online databases - Compendex, Embase, PubMed, ProQuest Materials science and ProQuest Biological Science - using Boolean search terms and truncation of relevant keywords. Included articles were published between 1989 and 2018. A predetermined methodological criterion was used in conjunction with a modified version of the Oxford Levels of Evidence to assess and grade the quality of selected articles.

RESULTS
13 clinical studies were included in this review. Based on the chosen search strategy and quality criterion, this review found a limited, low-quality evidence base for all included socket designs. All articles, except one, compared the various socket designs: Quad; Quad and MAS; MAS; Sub-Ischial and HiFi, against an IC socket as this was deemed the ‘standard of care’ design.

DISCUSSION AND CONCLUSION
Although Ischial Containment attained the highest volume of evidence, this socket design was not proven to be superior. The variety of biomechanical features pertaining to each socket design provide several advantages/disadvantages. Recommendations are made for future research.

ACKNOWLEDGEMENTS: I would like to thank Marlo Ortiz, R.J. Garrick, Randall Alley and Jay Martin for the images and additional information they provided regarding socket designs.

4.4.1.e

Survey of Prosthetists' Perspectives on Adjustable-Volume Lower-Limb Prosthetic Sockets

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BACKGROUND

Nearly 40% of individuals with lower limb amputation report that their biggest concern when receiving a prosthesis is comfort and fit [1]. One major contributor to socket discomfort is residual limb volume fluctuations throughout the day. Adjustable-volume sockets, utilize a dynamic mechanism to allow the user to modify the socket volume to manage fit and comfort. There is limited evidence on the efficacy of adjustable sockets, however.

AIM

The purpose of this study was to explore clinician perceptions and experiences fitting adjustable-volume prosthetic sockets.

METHOD

An anonymous online survey was developed and pilot tested with local prosthetists. The survey contained questions about prosthetists' demographics, whether they had previously fit an adjustable socket, whether these fittings were successful, and what challenges they experienced. The survey was distributed to certified prosthetists through advertisements at a national prosthetics conference and through oandp-l. We compared demographics between the groups who had and who had not fit adjustable-volume prosthetic sockets using Fisher's exact tests.

RESULTS

A total of 221 prosthetists responded to the survey. After screening, 195 responses were deemed eligible. A majority of the respondents had fit an adjustable socket (82.1%). There were no differences in prosthetist characteristics between those who had and had not fit an adjustable socket ($p > 0.081$). Respondents had fit a variety of adjustable sockets, with various degrees of perceived success (Fig 1). For successful fits, the most often reported challenges experienced were increased bulk (n=181), complicated fabrication (n = 141) and poor cosmesis (n =127). The most common reasons prosthetists had not fit an adjustable socket were lack of training (n = 15) and not believing they were effective (n = 12). However, 81.8% respondents would fit an adjustable socket if the obstacles they indicated were removed.

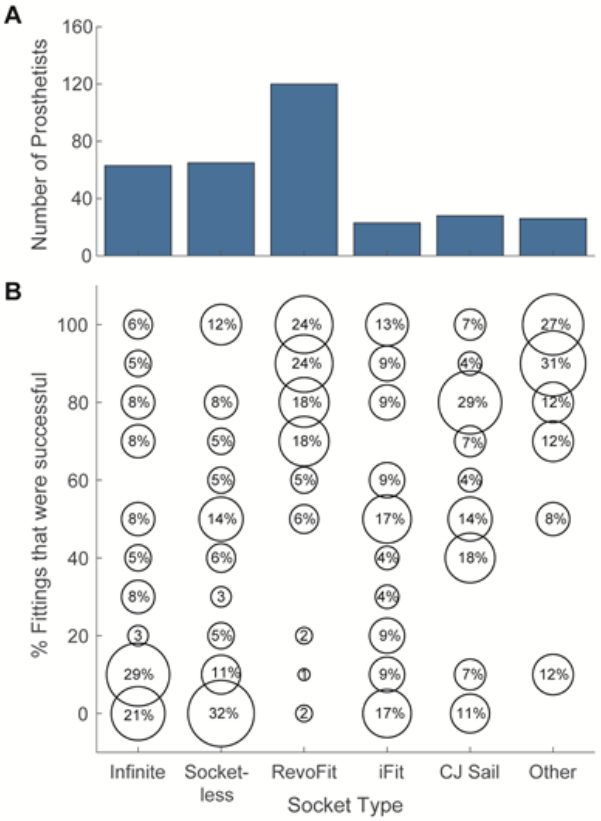

Figure 1. A) The total number of prosthetists who fit each type of socket. B) Bubble plot illustrates the percentage of fittings that were successful based on the criteria provided. The size of the bubble corresponds to the percentage of prosthetists who reported that level of success.

DISCUSSION AND CONCLUSION

A majority of the prosthetists surveyed were aware of adjustable prosthetic sockets and had fit them in their clinical practice. Prosthetists reported improved outcomes with more customizable designs. Adjustable socket technology may have several benefits, but prior to widespread use, prosthetists need guidance on proper candidate selection, best practice fitting and fabrication procedures, and clear evidence of functional advantages of these systems over traditional socket styles.

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ACKNOWLEDGEMENTS

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Symposium
Developing Countries

4.4.2
Prosthetics and Orthotics Education and Workforce in Sub-Saharan Africa Countries

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Abstract
According to the World Health Organization, people in need of assistive devices globally will be beyond two billion by 2050 and only one in 10 could get access to assistive product. Eighty percent of people living with some form of disability worldwide live in low resource countries. In sub-Saharan African, progress in training and provision of prosthetics and orthotics (P&O) service have been observed. However, service awareness and access to quality-of-life care satisfaction remain a challenge for the users. Due to lack of rehabilitation facilities and its affordability, the patients find it difficult to be fitted with P&O devices. The profession of P&O in sub-Saharan Africa faces many challenges in strengthening its educational ethos as well as meeting the huge demands on service delivery.

While there is a huge demand of P&O services in sub-Saharan Africa, this symposium will highlight the current training capacities and graduate workforce supply. We will discuss the potential factors influencing the demands such as the overall population, age-specific changes in population, the prevalence of diseases / injuries that require P &O services and the advance in technology.

The speakers with their professional experiences in the sub-Saharan African region, will discuss the current status of the P&O education in Africa in general. Specifically, presenters will highlight the service demands, workforce in sample countries in West and East Africa. Further action plans to address the current challenges the field is facing will be recommended.

Statement of the learning objectives
Attendees will be aware of the current development of P&O education and services in sub-Saharan Africa and major action plans for stakeholders will be discussed.

Symposium
Education

4.4.3
COVID-19: Facing the Pandemic-Related Challenges to Implement P&O Clinical Training

Christian Schlierf[1], Irena Karamehić[2], Nicolás Muñoz Buderus[3], Haifa Ben Ali[4], Ines Horrich[4], Marcelo Álvarez Carrascosa[5]

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Abstract
During 2020 the COVID-19 pandemic generated a global crisis and a challenge for education without precedent. Although Human Study develops P&O education programmes with blended learning as an essential component of its teaching methodology, many of the onsite activities needed to be cancelled or postponed, because of the restrictions motivated by the health crisis. Human Study, as many other institutions, had to adapt to this, and the organisation could develop several strategies to overcome the obstacles to make our specialised education arrive to the students and participants of P&O seminars and workshops around the world. The symposium will describe and discuss innovative solutions to implement clinical training activities threatened by the constraints of the pandemic consequences. An analysis of the results obtained with these strategies will be presented using data both objective (grades) and subjective (participants satisfaction surveys). The symposium will propose 3 topics: 1. Different solutions for the same problem: strategies applied in different contexts: Balkans vs. Ukraine, 2. A concrete case: DAFO online workshop in Pakistan. 3. Clinical Online Seminars: A temporary solution.

Statement of the learning objectives
Understand and analyse concrete examples of different innovative strategies applied by Human Study to make Clinical P&O Training arrive to students (Prosthetist-Orthotist and Associate Prosthetist-Orthotist programmes) and course participants, overcoming restrictions of the COVID-19 pandemic.

Free Paper Session
Prosthetics: Device Fabrication and Design

4.5.1.a

An Evaluation of Technology Adoption: Using 3D Scanners and Accelerometers in a Cambodian Prosthetics Clinic

Laura Diment[1], Ratana Sann[2], Raksmey Mutta Nguon[2], Sovansereyrathna Seng[2], Vannsnavy Sit[2], Peter Worsley[1], Alex Dickinson[1], Margaret Donovan-Hall[1]

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BACKGROUND
Digital technologies can provide information to support the conventional methods used to develop prosthetics. However, there is little research into which technologies are useful for prosthetists and prosthesis-users, particularly in low-resourced countries.

AIM
To explore the benefits and challenges of using 3D scanners for limb and socket shape capture and accelerometers to monitor prosthesis use in Cambodia.

METHOD
STAGE 1:
- An administrator, physiotherapist, prosthetist, and community worker were interviewed to understand current practices
- 12 clinicians and 12 prosthesis-users were interviewed to understand views on the proposed technologies

STAGE 2:
- A taught course on Research Methodology and Digital Technologies was developed
- A clinical study was designed

STAGE 3:
- 4 student-prosthetists completed the taught course and ran the clinical study with 20 lower-limb prosthesis-users. At commencement and 3-6 months later, participants completed a questionnaire and had their residual limb and socket 3D scanned. An accelerometer, embedded in the prosthesis, collected 10 weeks of activity data. The student-prosthetists and prosthesis-users provided feedback on the benefits and challenges of the technologies.

RESULTS
Clinicians and prosthesis-users were happy to use both technologies, but unfamiliar with actimetry. Suggested potential benefits were that 3D scans could capture residual limb changes and support creation of a mould for socket design that would be cheaper, quicker, more accurate and less messy than casting and enable in-community assessment. Prosthetists raised concerns that 3D scans would be less useful than plaster casting for socket fit and rectification. Prosthesis-users voiced concerns around whether accelerometers caused radiation exposure or electric shocks, and identified potential mental health concerns around data recording, access, and guilt about inactivity. They wanted an unobtrusive, lightweight, and waterproof device. Prosthesis-users and prosthetists hoped the accelerometers could compare activity levels between old and new prostheses, and remotely monitor prosthesis-use and whether the prosthesis was uncomfortable or broken.

DISCUSSION AND CONCLUSION
Stage 3 results show that the clinical study, designed in Stage 2, successfully addressed the concerns identified in Stage 1. At study completion, prosthesis-users averaged 8.8/10 for how comfortable they were with accelerometer monitoring and having 3D scans taken, and reported nothing negative about the technologies. The student-prosthetists easily learnt the technologies but found scanner and accelerometer technical errors frustrating. The study revealed the need for improved accelerometer battery durability and scanner reliability (glitches and movement artefacts).

ACKNOWLEDGEMENTS: Ethics: NECHR(311), ERGO(45577). Funding: EPSRC(EP/R014213/1).

4.5.1.b

Clinical Pressure Mapping Tool and Quantitative Data Dashboard to Assist Lower-Limb Prosthetic Fitting and Rehabilitation

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BACKGROUND
Prosthetic sockets are a vital component of lower limb prostheses that must be created for each individual. Creating prosthetic sockets is an iterative process, using a combination of clinical theory and experience. There is no standard measurement system to aid the creation of a prosthetic socket and no tool to guide prosthetists in their acquisition of skills, despite the physical health and quality of life impacts of an ill-fitting socket.

AIM
To create a biofeedback tool and data dashboard to display information from embedded sensors in the socket, in a clear and easy to use manner for clinical application.

METHOD
Iterations of a 3D model with a colour map, showing the pressure distribution in the socket were created, based on previously recorded measurements from a network of embedded sensors using interpolation. Once the interpolation methods had been optimised, the model was used in a desktop application that registers participant data, receives sensor data via Bluetooth and updates the colour map in real-time. The ability to save the data to a database was included, feeding a web-based data dashboard created for clinicians to access historical data about their patients and monitor changes.

RESULTS
The 3D model was created in Python using the VTK framework and a Radial Basis Function surface interpolation, with 144 vertex locations representing the sensor measurements. The desktop application enables the registration of participant data, Bluetooth transfer of data and real-time updating of the model was created using the PyQt5 framework and will be open source when distributed. The server side of the web application was created in Flask, with a SQL database. The software has been created modularly to enable any hardware to be connected with minor code modifications. The software must be downloaded onto the device to use the biofeedback tool; however, the dashboard can be accessed via any browser connected to the internet.

DISCUSSION AND CONCLUSION
The software enables prosthetists to view the pressure distribution within the prosthetic socket during fitting and observe the impacts of socket modifications without having to rely solely on subjective feedback from patients. Physiotherapists may use the tool to provide additional feedback during gait re-education. By using the data dashboard, clinicians can monitor changes to socket fit over time and help determine whether a new socket is required.

ACKNOWLEDGEMENTS: The authors thank The Royal British Legion for their funding.

4.5.1.c

Design of Customized, 3D Printed Prosthetic Feet Using the Lower Leg Trajectory Error Metric

Charlotte Folinus, Amos Winter

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BACKGROUND

We have previously used the Lower Leg Trajectory Error (LLTE) as a metric to predict the biomechanical performance and optimize the geometry of prosthetic feet, enabling users to achieve able-bodied walking patterns [1,2]. Although this design framework accommodates users of varying sizes and activity levels, traditional manufacturing methods make customization prohibitively expensive. 3D printing offers individual customization and the potential for improved foot performance.

AIM

The intent of this work is to use the LLTE framework to create 3D printed feet which satisfy mechanical requirements and meet user- and business-driven needs.

METHOD

Quantifying the material performance of available materials allowed us to compare the energy storage and return (ESR) potential of 3D printed materials with that of materials used in existing prosthetic feet. We selected and tested high-performance printed materials using standard tensile and flexural materials tests (ASTM D638 and D790, respectively) to develop a constitutive model for representing the material properties. We used the properties of an unreinforced nylon from Markforged to design 3D printed prosthetic feet which were optimized for users of varying body sizes and activity levels. We then verified the foot behaviour through static testing.

RESULTS

The nylon and nylon-based composite materials from Markforged offer higher strain energy density than nylon 6/6, which indicates that they have the potential to elastically store and return more energy than our current prosthetic feet (Fig. 1.a). In experimental testing, the measured vertical deflection differed from the finite element analysis (FEA) prediction by less than 2 mm (Fig. 1.b), verifying that the material model accurately captured the 3D printed foot's behaviour. The LLTE-optimized, 3D printed feet achieved high ESR (91%) with a mass of 0.27 kg.

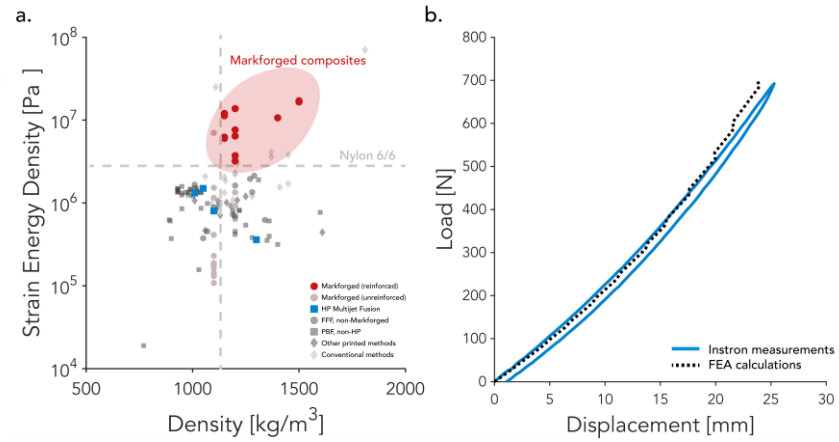

Figure 1: (a) Material selection criteria identify Markforged composites as high-performance compared to other materials. (b) Instron-measured and FEA-predicted displacements under loads applied at 13 cm from ankle.

DISCUSSION AND CONCLUSION

This initial validation shows we have the capacity to design and produce 3D printed prosthetic feet that can be customized for individual users. While unreinforced, printed nylon can offer similar performance to existing materials, feet designed using the LLTE framework and 3D printed composite materials could offer additional improvement. This warrants future mechanical and biomechanical testing to validate the behavior of composite printed feet, which we will include in our presentation.

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ACKNOWLEDGEMENTS: This work was supported by the Hanger Clinic.

4.5.1.d

Investigating the Response of Skeletal Muscle to Prosthesis-Related Loading Conditions: An Ex Vivo Animal Model

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BACKGROUND

The use of lower-limb prosthetics puts the soft tissue of the residuum, including the muscle envelop, under constant physical stress. To adapt to this unphysiological mechanical loading, the muscles need to maintain the balance between tissue damage and regenerative processes. However, in extreme cases of overload or with repeated impact, this balance may be disturbed [1], potentially leading to residual limb pain and Deep Tissue Injuries [2].

AIM

A new *ex vivo* model of rat skeletal muscle tissue was developed to quantify cellular damage from prosthesis-related loading protocols (Fig. 1a). Preliminary exploration of different imaging procedures and the relevance of results for prosthetic research and practice are discussed.

METHOD

Freshly isolated soleus and extensor digitorum longus muscles dissected from male Sprague Dawley rats were subjected to transverse compressive loading (9-32kPa through a 2mm indenter). Control tissues were held in the same conditions for the same time without loading. Tissues were subsequently processed for imaging by standard histological procedures, using H&E staining for visualising cell and tissue morphology and Procion Yellow for fluorescent dead cell staining [3]. In addition, tissue clearing methods were investigated to enable full tissue depth imaging by confocal microscopy. Furthermore, biochemical changes caused by cellular damage were visualised via multiphoton Raman microscopy of unstained samples.

RESULTS

During the maximum experimental time frame of 3h, the control samples showed only minor loss in cell viability. By comparison, the extent of mechanical damage in loaded tissues was readily distinguishable by imaging (Fig. 1b), with partial loss of striations, disrupted muscle fibres, increased interstitial space, and loss of cell viability. With careful control of the experimental setup, detailed imaging of local cellular damage in response to loading conditions could be obtained.

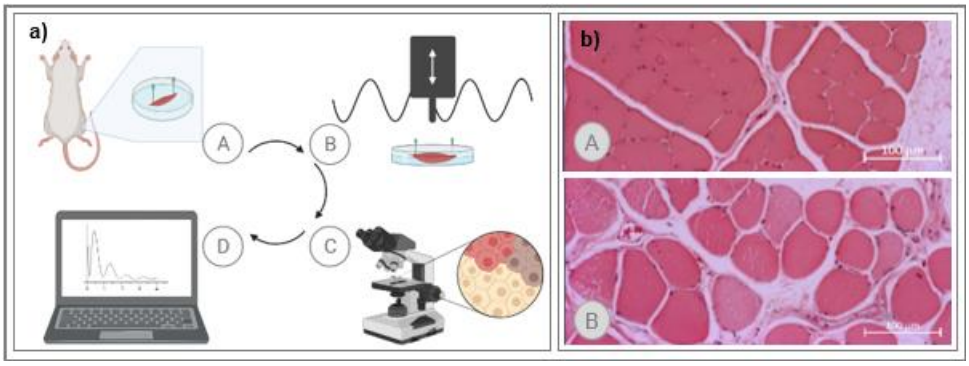

Figure 1a: Schematic of *ex vivo* animal model. A: Skeletal muscle dissection; B: Mechanical loading protocol. C: Image analysis for cell damage; D: Data analysis to establish the relationship between loading conditions and cell damage.
Figure 1b: H&E-stained cross-sections of skeletal muscle. A: Control tissue with polygonal cell morphology, little interstitial space, and uniform staining intensity; B: Damaged tissue with rounded cell morphology, increased interstitial space, and irregular stain intensity.

DISCUSSION AND CONCLUSION

Our preliminary studies present an *ex vivo* model and experimental procedures that are suitable for quantifying cellular damage from prosthesis-related loading conditions on skeletal muscle. Looking at this microscale will provide important insights into the adaptive capabilities of skeletal muscle. This can provide the basis for further research into the role of soft tissue deformation in limb pain and ulcer formation and could inform future directions for socket design and fit.

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4.5.1.e
Design Of A Novel Mechatronic System To Test Prosthetic Feet Under Specific Gait Activity Loads

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BACKGROUND
The Lower Leg Trajectory Error (LLTE) is a novel design metric used to predict the biomechanical response of prosthetic feet and optimize their design to replicate reference walking patterns [1,2]. Mechanically testing for the LLTE values of existing prostheses would enable amputee-independent measurements of walking performance. Machine-based testing has focused on endurance and strength [3,4], but our mechatronic system simulates walking loads by applying horizontal and vertical ground reaction forces (GRFs) independently at specific centres of pressure (CoPs).

AIM
The aim of this work is to create a device that measures the LLTE value of any prosthetic foot by accurately applying all the loads experienced during a specific walking activity and measuring the response of the foot.

METHOD
We designed a mechanical testing machine with three degrees of freedom to independently apply horizontal and vertical GRFs at specific CoPs. The required accuracy of the machine was set by the minimum just noticeable difference in stiffness for human subjects and determined using a library of prosthetic feet designed for users weighing between 40-200kg [5]. Using the relationships between the variables used to calculate LLTE and those used as inputs and outputs of the machine, we conducted a systematic error analysis to select the machine's geometry, actuators, and sensors so as to achieve the required accuracy.

RESULTS
The final design consists of two stepper motor-actuated linear stages (vertical and horizontal), a linear actuator-actuated tilting platform, and load cells beneath the stage platforms and in-line with the linear actuator. Encoders attached to the stages and the tilting platform shaft provide the prosthetic foot vertical and anterior/posterior deformation and shank angle measurements, which allows for the calculation of the LLTE. We chose the components and constants so that the predicted total LLTE accuracy of the device is less than the required ±0.005, which would allow the machine to differentiate between two prosthetic feet that differ in stiffness by ±3.7%. This accuracy rating applies to any prosthetic foot designed for subjects weighing between 40-166kg.

DISCUSSION AND CONCLUSION
We created a device that can accurately apply the loads experienced when walking. This departs from traditional prosthetic testers and gait simulators that solely control vertical loads and ground angle. With this device, we can compute the LLTE, a novel metric that evaluates performance of prosthetic feet without the need for human subject testing. This will allow for a systematic and amputee-independent evaluation of prosthetic feet walking performance, allowing for further improvements of prosthetic foot designs.

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Basic Instructional Course
Rehabilitation Medicine and Surgery

4.5.2
Recent Advances in the Management of Spasticity in People with Neuromusculoskeletal Conditions

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Abstract
Spasticity is a common symptom among individuals with neurological conditions (e.g., spinal cord injury, stroke, and cerebral palsy) presenting to the orthotics and prosthetics clinics. If left untreated or poorly managed, spasticity can cause discomfort and stiffness, significantly affecting activities of daily living such as walking, transferring, personal hygiene, and dressing. Later spasticity may lead to significant pain, contractures, joint subluxations or dislocations, peripheral neuropathy, and pressure injuries.

The main objective of this short instructional course is to elevate the attendee's knowledge and skills in the evaluation and management of spasticity. It will equip attendees with the essential knowledge to take an active role in spasticity management, particularly where high medical costs prevent people from receiving special care for spasticity. This course delivered by experts in the field will introduce strategies to differentiate and identify different patterns of spasticity, discuss different focal and regional interventions used for the management of spasticity, including the potential novel use of transcutaneous nerve stimulation. This learning module will provide attendees with an overview of the most frequently used spasticity measures and scales to support understanding and awareness of assessing individuals with spasticity. It will also discuss spasticity regulation benefits and how on-demand spasticity could be used to help with standing and transfers. The course will continue with a case presentation of spasticity management of a person with spinal cord injury. Upon completing this course, attendees should be capable of planning and executing these procedures with a higher degree of confidence and efficiency.

Statement of the learning objectives
The main objective of this short instructional course is to elevate the attendee's knowledge and skills in the evaluation, management, and on-demand utilization of spasticity.

Symposium
Developing Countries

4.5.3
Humanitarian Consequences of Migration and Disability in Latin America

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Abstract
Migration is an important topic for the Latin American region, especially with the always-evolving Central American migration pathway to the US and the Venezuelan - Colombia migration crisis. What is not well known or discussed on a large scale is the link between migration and physical disability, how certain forms of migration, such as displacement and irregular migration, are associated with increased vulnerability and that mobility impairments further increase the vulnerability of migrants. Current literature recognizes that “disabled persons are one of the most vulnerable and socially excluded groups in any displaced or conflict/violence affected community.” [1]

The ICRC has experience in this field in the Latin American context. In Central America, for example, it provides physical rehabilitation and mental health services, in synergy with relevant stakeholders, to migrants that suffer from serious injuries caused by falling off “la bestia” (the freight train connecting the region with the US border). Also, since 2018, the ICRC has been putting considerable effort into South America’s Northeastern region to ensure that Venezuelan migrants in transit are treated with dignity, as well as to help migrants with physical disabilities affected by this humanitarian crisis to improve their quality of life. These migrants are particularly vulnerable, since they have not been able to have access to physical rehabilitation services in their home country, and many of them have been victims of violence.

Statement of the learning objectives
To improve strategies to mitigate risks posed by migration to disabled people by engaging related actors on disability, the affected population’s humanitarian needs, the ICRC’s response, available data and key risks identified.

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Posters

Poster Presentation
Orthotics: Lower Limb Neurological

5.01
Peroneal Nerve Palsy after Covid: What is the Role of Ankle Foot Orthosis during Post Covid Rehabilitation?

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BACKGROUND
Rehabilitation is a cornerstone to improve functional outcomes after severe coronavirus disease 2019 (COVID-2019), but to our knowledge, no previous studies assessed the effects of rehabilitation treatment in post intensive care unit COVID-19 patients with peroneal nerve palsy.

AIM
The aim of this case series was to present the rehabilitative approach to peroneal nerve palsy in post intensive care unit COVID-19 patients.

METHOD
Eight patients were included in the study after intensive care unit hospitalization for COVID-19. Participants were affected by peroneal nerve palsy assessed by electromyography (EMG). All patients underwent a specific rehabilitation program including strengthening, mobilization, balance, and gait training. To promote gait recovery, dynamic ankle-foot orthosis (AFO) was immediately prescribed. Moreover, patients received neuromuscular electrical stimulation of the anterior tibialis muscle 5 days per week once a day for 30 minutes for 3 weeks. Functional outcomes assessed were: a) Manual muscle test (MMT) of dorsiflexor muscle; b) 6 minutes walking test (6MWT); c) Short Physical performance Battery; d) Fatigue Severity Scale (FSS).

RESULTS
The study cohort was composed of 6 males and 2 females. Three patients were affected by bilateral peroneal nerve palsy. The age of study participants were 59.13 ± 10.77 years old and BMI were 23.75 ± 3.28 kg/m2. Length of hospitalization in intensive care unit were 39 ± 7.63 days, while mechanical ventilation was performed for 33.88 ± 9.07 days. EMG showed axonal neuropathy for all patients included (n: 8; 100%). After the treatment, MMT varied from 0.38 ± 0.52 to 1.13 ± 0.99. Improvement of strength was recorded in 4 patients (50%). Moreover, there was recorded an improvement of 6MWT (162.11 ± 118.13 to 289.77 ± 152.27), SPPB (1.5 ± 1.19 to 7.5 ± 4.66). FSS (39.75 ± 19.08 to 32.25 ± 17.45) in all the patients.

DISCUSSION AND CONCLUSION
Gait function should be restored as soon as possible post-intensive care unit COVID-19 patients, taking into account neuromuscular complications related to the disease. Therefore, we recommend early detention and management of foot drop with dynamic AFO in order to promote functional recovery and physical performance in the complex rehabilitation management of post-COVID patients.

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5.02

Effects of Non-Restrictive Sensory Insoles in Treatment of Idiopathic Toe Walking: A Single Case, Longitudinal Follow-up Study

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BACKGROUND

Orthotic treatment of individuals with Idiopathic Toe Walking (ITW) typically includes limitation of motion at the foot and ankle to promote initial heel contact (1). These approaches control the kinematic expression of ITW but might not be based on the aetiology. Recent studies confirm sensory differences in some children with ITW (2,3), enabling different treatments.

AIM

To determine the long-term effects of a sensory-stimulating insole on walking in a child with ITW.

METHOD

Over a 15-month period, we analysed the gait of a 7-year-old child with ITW who had mobile ankle joints and was defined as a sensory-seeker on the Short Sensory Profile. Following informed consent, we fitted her shoes with flexible, textured sensory insoles (Naboso Technology, Brooklyn, NY) and instructed her to wear them during daily activities. During four sessions we conducted instrumented 3D gait analysis both barefoot and while wearing the shoes with insoles and assessed ankle range of motion (ROM) using a weight-bearing lunge test.

RESULTS

In the insole condition, 100% of steps showed initial heel contact, while barefoot initial contact varied over time. A consistent improvement in gait deviation index (GDI) was observed in both conditions over time. GDI improved 20 units with insoles and 12 units in the barefoot condition from the first to the fourth visit. Walk Ratio improved about one cm/(step/min) in each condition (Fig. 1). Ankle ROM increased in the second visit by about 3˚ on the right side and 7˚ on the left side, then gradually decreased in the next two visits, although it remained around one degree greater than the initial visit. Both walking speed and cadence had a consistent decrease over time.

Figure 1Improvement of Walk ratio in both conditions over four visits.

DISCUSSION AND CONCLUSION

Results for this single subject suggest that sensory insoles improved gait, with possibly diminishing effects over time. Additional analysis is needed to distinguish between the effects of insoles vs. shoes alone. The decrease in speed and cadence may reflect a more confident gait pattern. Furthermore, this subject revealed bilateral asymmetry, which is unusual in children with ITW, meriting additional study. Alterations in sensory stimuli might be a solution to keep consistent results, which should be considered in future studies.

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5.03
The Application of a Configurable Gait Evaluation Orthosis and Method to Optimization of AFO Design

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BACKGROUND
There are many types of ankle-foot orthoses used to treat patients with gait deficits. Through mechanical testing, these AFOs may be classified as one of four basic functional types. The clinical impact of an AFO type may be difficult to determine prior to fitting the definitive orthosis. However, a highly configurable, prefabricated gait evaluation orthosis capable of simulating the mechanical characteristics of these different AFO functional types may be used to help determine the optimal type prior to fabrication.

AIM
This paper summarizes the evidence and application of a highly configurable gait evaluation orthosis capable of simulating the mechanical behaviour of four basic AFO functional types to orthotic prescription.

METHOD
A highly configurable, prefabricated evaluation orthosis with a multi-function ankle joint was developed and used to simulate the four AFO functional types. These functional types were classified as: non-articulated, standard action, resisted articulation, and multi-function. The orthosis was used to evaluate two patients; one with CVA and the other with CMT. During the evaluation, the orthosis was configured as each of the four functional types while the patients were evaluated using slow-motion observational gait analysis (OGA) and Timed Up and Go (TUG) outcome measures.

RESULTS
The slow-motion video OGA demonstrated systematic influence of the evaluation AFO on gait variables for foot position at IC and knee stability in early and late stance for both the CVA and CMT patients. The TUG outcome measure results for the CVA patient supported kinematic observations with the preferred AFO type corresponding to the least TUG time. The TUG results were less differentiated for the CMT patient, however patient feedback and the selected functional type were correlated with observations of gait kinematics during AFO tuning.

DISCUSSION AND CONCLUSION
The gait evaluation orthosis provided a convenient means to evaluate the impact of four AFO functional types on patient function. The OGA combined with TUG outcome measure was a useful method to select the biomechanically-optimal AFO functional type when combined with patient subjective feedback. This approach to patient evaluation and AFO functional type selection may help to more reliably determine the optimal AFO design prior to fabrication of the definitive orthosis, improving patient outcomes.

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5.04

Patterns in Early Gait Post-Stoke as Indicators of Rehabilitation Potential. A Secondary Data Analysis Study

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BACKGROUND

Recovery of community walking capacity is a common target in stroke rehabilitation. This is often predicted from the gait speed achieved post rehabilitation [1]. The propulsion required to move the body forward is generated, primarily, from the moments about the hip and ankle during early stance, terminal stance and swing. The angle created by the lower limb during these phases is a key factor in generating forward propulsive force.

AIM

This study aimed to identify patterns in the gait (speed and shank to vertical angles (SVA)) of patients early after a stroke that might explain their potential to recover the walking speeds associated with a return to community walking.

METHOD

The study was a secondary data analysis of existing data which were collected from participants following a stroke [2]. The data were collected at three intervals through the rehabilitation journey: Baseline (before rehabilitation commenced), Outcome (immediately after 6 weeks of rehabilitation) and Follow-up (3 months later), using a Vicon motion capture system. 110 datasets were reviewed, following application of exclusion criteria 33 participants with complete 'walks' data for the three time periods were analysed.

RESULTS

Mean walking speed increased for 95% of the participants. At Baseline 61% achieved slower than 0.4m/s, 28% achieved 0.4-0.8m/s and 11% achieved greater than 0.8m/s. At Outcome 39% achieved <0.4m/s, 33% achieved 0.4-0.8m/s and 28% achieved 0.8m/s or greater. Two participants achieved walking speeds considered 'normal' (>1m/s). At Follow-up 23% achieved <0.4m/s, 38% achieved between 0.4-0.8m/s and 39% achieved greater than 0.8m/s with two participants achieving 'normal' walking speed (as above).

Baseline shank to vertical angles (SVAs) (for the affected limb) ranged from -0.4^{o} (reclined) to +20.8^{o} (inclined) at initial contact and -13^{o} to -57^{o} at foot-off. The Outcome SVA range was +14^{o} (inclined) to +19^{o} (inclined) at initial contact and -7.1^{o} (reclined) to -59.4^{o} (reclined) at foot-off.

Pearson correlation coefficient indicates a significant trend between the change in gait speed and the SVA at initial contact and foot off.

DISCUSSION AND CONCLUSION

The data showed two participants achieved a 'normal' walking speed (>1m/s) and one of these would be safe using pedestrian crossings (1.2m/s required) [3].

The SVA pattern indicated peak shank reclination at initial contact and peak inclination of the shank at foot-off. The Pearson calculation indicates that there may be a significant correlation between the change in gait speed and the SVA however due to the small sample size this is not statistically significant without further validation.

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Poster Presentation
Orthotics: Lower Limb Orthopaedic

5.05
Enhancement of Compliance and Clinical Outcome through Patient Specific 3D Printing Orthotic Treatment for Hallux Valgus Patients with Foot Pain RCT

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BACKGROUND
Hallux valgus (HV) is a common foot deformity which is defined as a degenerative joint problem. Patients having HV often suffer from pain and have limited mobility and stability. Foot orthotic management was shown to be effective in the reduction of foot pain, enhancement of postural stability and reduction of fall rate. However, hand-crafted fabrication techniques are more time consuming against 3D printing. Future research will benefit from clearly addressing how the 3D printing processes improve upon traditional fabrication methods.

AIM
- Determine process requirement based on the clinical needs
- Define an overall process structure for 3D scanning and 3D printing in orthotic management for HV
- Evaluate the potential clinical enhancement of orthotic treatment effectiveness for HV patients through 3D printing technology.

METHOD
Subjects were randomized using sealed envelopes into intervention group and control group. Intervention group was managed by 3D scanning and 3D printing method. Control group was managed by conventional hand-craft method. The study included 84 patients with 168 feet complete and fulfil the requirement of data collection. 42 patients (37 female, 5 male) were randomly assigned to each group between intervention group (3D printing) and control group (traditional method). The primary outcome of the study is the changes of forefoot pain (VAS). The secondary outcomes are including the (i) AOFAS forefoot score (Chinese), (ii) Compliance of and tolerance with orthoses, (iii) Hours per day of orthoses used and (iv) the lead time for the fabrication of orthoses on each approach.

RESULTS
The outcome assessment was performed at baseline, 1st follow up (average 67.4 days), and 2nd follow up (average 152.5 days). The change of VAS score of forefoot pain was observed in both group, with no significant difference within and between groups (p>0.05). For AOFAS forefoot score, there were a significant difference observed on pain, activity limitation and support requirement, MTP joint motion and overall score within intervention group (p<0.05); and pain, callus related hallux and MTP-IP, and overall score were observed within control groups (p<0.05). For the between groups comparison, the footwear requirement of control group was significantly lesser than intervention group at 2nd follow up (p<0.05). The alignment of intervention group had a significantly better improvement than control group at 2nd follow up (p<0.05). The time consuming of fabricating orthoses at intervention group (38.6 mins) was almost half time upon control group (79 mins).

DISCUSSION AND CONCLUSION
The estimated fabricating time (3D printing time) and use of material (filament) from the software of 3D printing are quite different from the actual expenditure of the material and 3D printing time especially at the cases of printing defect. That may be a consideration for the further study in this field for foot orthotic treatment of HV patients.

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5.06

Effect of Types of Ankle-Foot Orthoses on Energy Expenditure Metrics during Walking in Individuals with Stroke: A Systematic Review

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BACKGROUND
The most common problem secondary to stroke is walking difficulty, including slow velocity, instability, and energy inefficiency. The lower walking speed along with the higher energy expenditure disposes stroke patients to a sedentary life, which affects cardiovascular function. Generally, the main goals of rehabilitation are to improve gait stability and possibly to reduce energy consumption. Orthotic devices, especially ankle foot orthoses (AFOs), can be used to partially improve the gait pattern, reduce metabolic cost and increase walking speed in stroke survivors.

AIM
This systematic review is aimed at evaluating the efficacy of AFO types and comparison between them on the energy expenditure metrics of walking in individuals who had suffered a stroke with (sub)acute or chronic evolution.

METHOD
The following databases were searched; PubMed, Scopus, ISI Web of Knowledge, Embase and Cochrane Library based on the population intervention comparison outcome (PICO) method. The methodological quality assessment of 30 included studies was conducted based on Downs and Black checklist (1). Energy expenditure metrics *of walking* have been measured by evaluating the total energy consumption, net energy consumption, total energy cost, net energy cost, net energy cost in physiological cost index, heart rate, respiratory rate, and total mechanical work. Furthermore, the vertical displacement of COM has been investigated in relation to the energy cost of walking.

RESULTS
A total of 15 trials involving 195 participants were selected for the final evaluation. All trials, except one, examined individuals in chronic phase. Although the evidence from the selected studies was generally weak, the consensus was that an AFO may have a positive immediate effect on the energy expenditure metrics including energy cost, physiological cost index, mechanical work and vertical centre of mass trajectory on the affected leg, in both overground walking and treadmill walking in adults with chronic stroke. There were insufficient studies to evaluate the medium term efficacy of wearing an AFO combined with gait training on metabolic cost parameters during ambulation. There were also insufficient studies for comparison among different designs of AFOs.

DISCUSSION AND CONCLUSION
Although the studies were somewhat weak in scientific rigor and had moderate risks of bias, this review has demonstrated that an AFO can make an immediate, short time improvement in the energy cost of walking phase, while the AFO is worn. Concerning the effects of long-term use of an AFO along with training, there was largely insufficient evidence to reach a valid conclusion. There were also insufficient data for comparison among different designs of AFOs.

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5.07

Knee Joint Movement and Muscle Activity Changes in Stroke Patients with Continuous use of Knee-Ankle-Foot Orthosis that Adjustable Knee Joint

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BACKGROUND

Knee-ankle-foot orthoses (KAFO) provide better support of the knee joint are therefore effective for walking practice in stroke patients who have difficulty with weight bearing. So KAFO are commonly used in recovery phase rehabilitation for stroke patients in Japan. Sustained use of ankle-foot orthoses is thought to decrease the muscle activity.[1] So there is concern about disuse atrophy of the knee extensor muscles when using a highly fixed KAFO because it limits the motion of the knee joint.

AIM

The objective of this study was to evaluate the knee joint movement and muscle activity ratio changes in stroke patients in the recovery phase after using a KAFO with an adjustable knee joint for 1 month.

METHOD

Participants were 8 patients in the recovery phase of stroke who were prescribed a KAFO. We measured knee joint angles as well as the electromyography activity of the vastus medialis and biceps femoris during walking. Measurements were taken first at 2 weeks after delivery of the orthosis and again 1 month later. The KAFO prescribed was equipped with an adjustable SPEX knee joint and a double Klenzak ankle joint. SPEX knee joints can be adjusted either by spring or by rod to change the range of motion of the knee joint flexion; in this study, we used the rod.

RESULTS

Figure shows the average values of knee joint angles and %EMG of the vastus medialis in participants. At 1 month after the initial measurement, the knee joint flexion angle decreased from initial contact to mid-stance compared with the initial measurement. In knee joint movement, the %EMG of the vastus medialis tended to increase from loading response to mid-stance in both the initial measurement and at 1 month later compared with knee joint fixation. When the knee joint was adjusted to allow up to 30° of flexion, the knee joint angle at initial contact and the minimum flexion angle of the gait cycle decreased significantly between the first and second measurements. When knee joint flexion was 30°, the muscle activity ratio of the vastus medialis was significantly increased in loading response and mid-stance compared with when the knee joint was fixed.

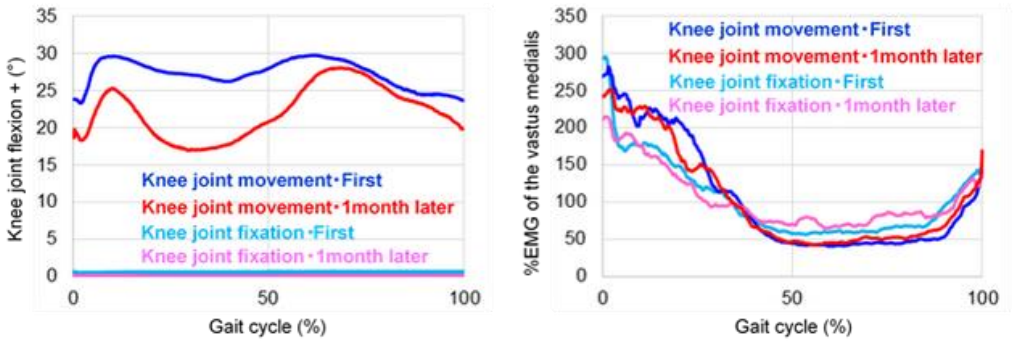

Figure 1. Average values of the 8 participants

DISCUSSION AND CONCLUSION

In knee joint movement, the %EMG of the vastus medialis at 1 month later was significantly increased in loading response compared with knee joint fixation. Furthermore, the flexion angle of the knee joint at initial contact was significantly reduced, which may facilitate activity of the vastus medialis in loading response. Setting the knee joint of the KAFO in accordance with the knee joint movement may immediately increase the muscle activity ratio of the vastus medialis from loading response to mid-stance.

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5.08

Relationship between Wearing Pressure of Flexible Knee Orthosis and Muscle Activity during Standing-up: A Pilot Study for Knee Osteoarthritis Patient

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BACKGROUND

The advantage of a flexible knee orthosis is that adjusting the hook-and-loop fastener allows to change wearing pressure for fixation[1)]. Wearing pressure changes during movement, but it is desirable to continuously provide adequate wearing pressure. Thus, the new flexible knee orthosis that dynamically change wearing pressure should be developed. To develop the new flexible knee orthosis, it is necessary to investigate the relationship between wearing pressure and kinesiology.

AIM

The aim of this study was to investigate the relationship between wearing pressure of flexible knee orthosis and muscle activity, for a knee osteoarthritis patient.

METHOD

The muscle activities during standing-up were measured with four wearing pressure conditions. Four conditions were “Control (without using an orthosis)”, “Low Pressure (wear the brace with lowest pressure to hold)”, “Middle Pressure (wear the brace as usual pressure)” and “High Pressure” (with maximum pressure). A surface electromyogram (EMG) was used to measure muscle activity. Surface electrodes were attached to rectus femoris (RF), vastus medialis (VM), vastus lateralis (VL), biceps femoris (BF), tibialis anterior (TA), gastrocnemius (GC). Integrated EMG (iEMG) was calculated and normalized by the maximum voluntary contraction (MVC) of each muscle. All experimental procedures were approved by the ethics committee of Fukuoka Tenjin Medical Rehabilitation School (approval number 2020-1).

RESULTS

Figure 1 shows the relationship between muscle activity and wearing conditions in six lower limb muscles. The results indicated that muscle activities of three conditions (Low, Middle and High Pressure) were smaller than “Control” in all muscles. In addition, muscle activities of “Low Pressure” were smaller than “Middle Pressure”, and “High Pressure” in all muscles.

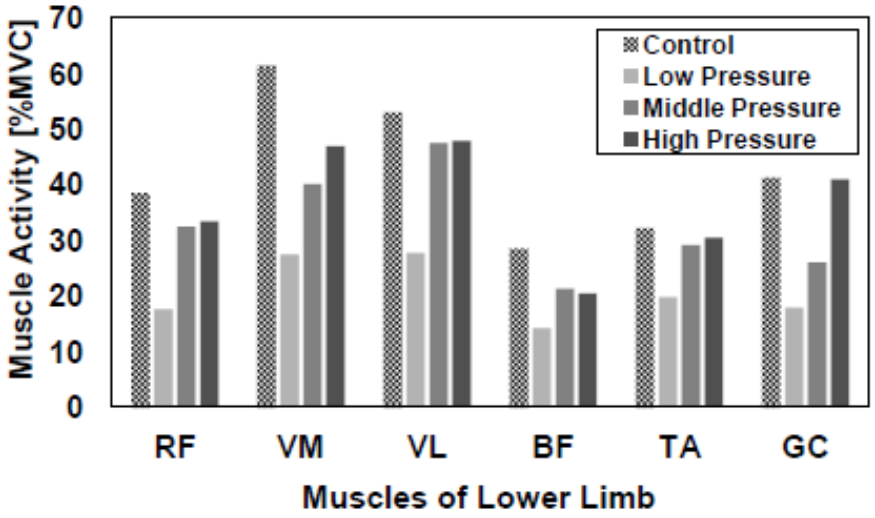

Figure1 Relationship between muscle activity and wearing pressure

DISCUSSION AND CONCLUSION

Wearing a flexible knee brace can reduce the activity of the lower limb muscles when standing -up. Especially, Low Pressure condition contributed to reduce muscle activity than other conditions. Furthermore, previous study reported that low wearing pressure could improve knee joint pain and body sway[2)]. These findings suggest possibility that low wearing pressure could be suitable to reduce load of muscle and joint for knee osteoarthritis patient.

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5.09

Impact of Two Types of Ankle Braces on the Performance for the Repetitive Rebound Jump in Healthy Adults

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BACKGROUND

Ankle brace decreases vertical jump height due to restricted sagittal ankle range of motion during squat jump (Mann et al., 2018). However, it is also important for athletes to jump not only higher but also in minimal contact time. Because, in competition of basketball, if an offensive player can jump high, quickly, and repetitively, this player is likely to disrupt the timing of defenders, draw a foul, and shoot the ball. Repetitive rebound jump could be assessed for that performance.

AIM

This study aimed to investigate the impact of restricted sagittal ankle motion due to ankle brace on the repetitive rebound jump performance in healthy adults.

METHOD

Study design was repeated-measure test and approved by Ethical Committee of Hiroshima University. Twenty healthy volunteers performed the repetitive rebound jump under the three conditions: no-brace, Filmista Ankle (NIPPON SIGMAX), and A1 (NIPPON SIGMAX). Filmista Ankle is film-like soft brace and A1 is soft brace covered ankle joint. Outcomes were maximum jump height, contact time, and rebound jump index (RJ-index) in second to sixth RJ. The RJ-index is obtained by dividing the jump height by the contact time. The sagittal ankle motion (plantarflexion at toe off and maximum dorsiflexion) was calculated. A two-factor univariate analysis of variance with repeated-measure and pairwise comparisons were conducted on any significant findings.

RESULTS

Figure summarizes the impact of two types of ankle braces on the performance for the repetitive rebound jump. The pairwise comparisons revealed a significant decrease in jump height at sixth RJ in A1 brace (25.6±6.6 cm) than no-brace (27.4±6.2 cm) ($p<0.05$). As well, plantarflexion at toe off and maximum dorsiflexion significantly decreased in A1 brace than no-brace at sixth RJ ($p<0.01$).

DISCUSSION AND CONCLUSION

The A1 with high degree of restriction for the sagittal ankle motion decreased the jump height at the end of RJ. RJ-index also tend to decrease so that these results indicate the restricted sagittal ankle motion due to the ankle brace decreases the repetitive jump performance. The ankle brace that greatly restricts sagittal ankle motion may be unsuitable for sports that involve frequent jumping.

5.10

Critical Analysis of Digitalization by 3D Printing in Orthopaedic Technology with the Focus on Night Splints for Children

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BACKGROUND

Increasing digitalization has also brought about a change in O&P. Manufacturing techniques are becoming increasingly digital. New technologies like 3D printing are designed to replace traditional processes and make work easier for trained specialists. The content focus is primarily on the consideration of the digitization of orthopaedic technology using 3D printing. The focus will be on night splints for children and adolescents.

AIM

The aim is to critically examine the comparison of the digital manufacturing process of a night splint for children using 3D printing with the traditional handcrafted process. Focus on economic and ecological factors.

METHOD

The comparison of the digital manufacturing process of a night splint for children with the traditional handcrafted manufacturing process was examined in more detail. The various factors of sustainability, manufacturing and production time, costs and customizability were considered and compared. Since sustainability is a difficult factor to measure, calculations were made for material costs and transport distances. Measurements were taken from the procurement of materials to the manufacture of the finished product. However, reusability was also examined. In addition, comparative calculations of the time required by different CPOs and cost calculations were made. In addition, the possibilities for customization were examined and presented. [1]

RESULTS

It was found that the material costs of the traditional process outweigh the costs of the digital process for a night splint, especially due to the plaster production. In addition, more time can be saved through digital production. This also leads to a reduction in the workload of the CPO. The pure material costs outweigh the costs of digital creation using 3D printing. But its overall cost factor is more advantageous due to the elimination of storage costs and the time savings. One of the greatest advantages of the digital processes is the ability to customize. Digital manufacturing offers significantly more possibilities for individualization of a night splint for children than the traditional process. These possibilities also lead to greater acceptance of the night splint by children and young people. [1]

DISCUSSION AND CONCLUSION

It can be seen that the digitalization of orthopaedic technology is leading to a change in creating products both economically and ecologically. Even if the advantages of 3D-printing cannot yet be fully exploited, this is a big step towards a workshop supported by computers. This studies reflect only a small sample, a more comprehensive study comparing the carbon footprint of the manufacturing process could provide more detailed information on sustainability. [1]

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5.11

Effects of a Pamphlet for Pavlik Harnesses to Educate Parents of a Child with Developmental Dysplasia of the Hip

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BACKGROUND

In order to use orthoses effectively, the user must understand their purpose and the methods of donning/doffing. For paediatric orthoses, it is necessary for family members to understand their objective and donning methods. However, it may be difficult to explain the purpose and method of donning verbally. Therefore, we made a pamphlet for Pavlik Harnesses for children with developmental dysplasia of the hip (DDH).

AIM

The purpose of this study was to evaluate the effectiveness of the pamphlet for Pavlik Harnesses to improve user understanding.

METHOD

We conducted a survey at 60 orthotics workshops to establish the goals of the pamphlet. Based on the results, we created a pamphlet that describes how to don and doff Pavlik Harnesses including illustrations and its precautions, and an explanation of DDH. 16 P&O students were divided into two groups. The intervention group received information about Pavlik Harnesses using the pamphlet. The control group learned only verbally. An examination on basic knowledge of DDH was performed and a practical test was also performed to evaluate the accuracy of donning Pavlik Harnesses.

RESULTS

According to the survey, 40% of the company had already used visual documents to explain the Pavlik Harness. It was also clarified that in most cases, orthotists mainly play the role of explaining the orthosis to family members. There was no significant difference between the two groups in the examination scores ($p = 0.748$). Significant difference was found in the practical test scores ($p = 0.022$).

Figure： An Pamphlet for Pavlik Harness

DISCUSSION AND CONCLUSION

The pamphlet contained illustrations to explain the donning of the orthoses more clearly, leading to better understanding. The results of the examinations indicated that the pamphlet was not effective towards understanding better the basic knowledge because there were not enough illustrations. It was found, however, that the pamphlet may be effective in improving the donning skills of the Pavlik Harness.

ACKNOWLEDGEMENTS: We are grateful to Kobe College of Medical and Welfare Sanda Campus for supervising this study as a graduation research.

5.12
A Stance Control Orthosis with Variable Yield Functions: Case Studies

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BACKGROUND
Conventional KAFOs are commonly locked throughout the gait cycle [1]. Some stance-control orthoses are locked during stance and free during swing [1] but have little adaptation for other activities of daily living (ADL). Users may require kinematic compensations [2], which, over time, could lead to health problems. A novel microprocessor controlled KAFO (MPKAFO) has been developed to provide variable knee resistances for walking and ADLs.

AIM
Assess the effects of the microprocessor-control of a KAFO.

METHOD
Case studies were collected from patients who were fitted with the device providing microprocessor control of knee resistance. Clinical measurements of muscle strength (e.g., Oxford knee score) and joint range-of-motion limitations were recorded. Patients completed a number of patient-reported outcome measures and functional clinical tests using their previous KAFO and the MPKAFO. These included the Orthotics and Prosthetics User Survey (OPUS), Stairs Assessment Index, Hill Assessment Index, two-minute walk test (2MWT) and timed-up-and-go (TUG) test.

Level walking, stand-to-sit and (when possible) stairs descent motion capture and force data were collected for the MPKAFO and compared to either a locked (level walking, stairs descent) or an unlocked (stand-to-sit) KAFO.

RESULTS
The different cases demonstrated the improved mobility provided by the MPKAFO's functions for patients with various lower limb deficiencies and comorbidities.

One case was of an ex-military, 29-year-old male who had paralysis of the right leg from a service injury. He reported improved scores in the subjective outcomes, observed to perform more natural gait on hills and stairs, and increased his walking speed with the MPKAFO.

Another case concerned a 48-year-old, para powerlifting competitor who used a KAFO on her left leg after developing osteoarthritis with resultant muscle weakness and knee instability. As well as improved performance in functional tests with the MPKAFO, she reported reduced frequency of pain in her affected limb.

Gait analysis demonstrated fewer gait compensations. Also, the variable knee flexion resistance during stand-to-sit allowed substantial reductions in inter-limb loading asymmetry.

DISCUSSION AND CONCLUSION
Microprocessor-control can be employed in orthoses to provide improvements in mobility and the functional execution of ADLs. These benefits have been observed for a broad patient population.

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5.13
Estimating Patient Specific Material Properties for Soft Tissues in the Residual Limb

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BACKGROUND
Over the past two decades, biomechanical modelling has made a significant contribution to the current understanding of soft tissue mechanics (1,2). The efficacy and fidelity of biomechanical models require accurate information on geometry and soft tissue properties. Accurate information on the residual limb geometry can be readily obtained from medical images. However, material properties are often estimated based on literature reports.

AIM
This case study aims to establish a methodology and to demonstrate the feasibility for estimating structural material properties for soft tissues in the residual limb using Finite Element computational modelling.

METHOD
Soft tissue material properties for the residual limb of a patient with a trans-tibial amputation were estimated through a series of quasi-static compression tests. In each test, a known pressure (30, 60 or 100 mmHg) was applied to the residual limb through an MRI-compatible sphygmomanometer (Cone Instruments, USA). MRI scans taken for each test were segmented using *ScanIP* (Synopsys, California, USA) to obtain geometries of the uncompressed and the compressed states of the residual limb. Non-rigid ICP was performed to calculate soft tissue deformation, and the force applied was calculated for each test (force = pressure * area). Finally, a piecewise linear model was fitted to the force-deformation data.

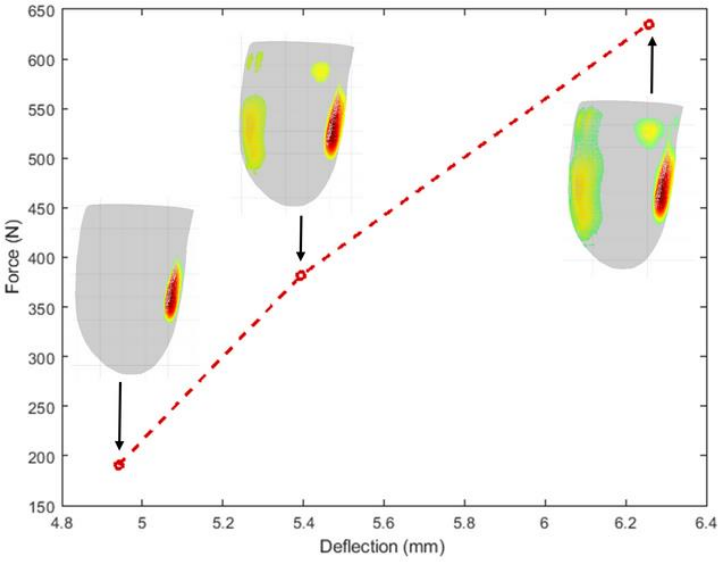

Figure 1: Maximum Soft Tissue Deflection vs Force Graph. The Figure demonstrates the areas of deformation on the residual limb when the force was increased from 190N to 635 N. The areas marked by red indicates the 90th percentile, while yellow and green areas indicate the 70th and 50th percentiles of the tissue deformation.

RESULTS
The maximum tissue deformation measured at 30 mmHg, 60 mmHg and 100 mmHg were 4.9 mm, 5.4 mm, and 6.3 mm, respectively (Fig 1). The contact area was estimated to be 476.5 cm^2. As a result, the forces applied during each of the compressed states ranged from 190 N (at 30 mmHg) and 635 N (at 100 mmHg), approximately. The location of the maximum deformation coincided with the centre of the area in contact with the inflated side of the sphygmomanometer.

DISCUSSION AND CONCLUSION
This work contributes to the development of accurate computational models of the mechanical contact between the residual limb and encasing socket. Such models can aid current socket design and customisation process in an effort to reduce the risk of tissue injury, time, materials and workforce required for design and fabrication of a best-fit prosthetic socket, and to improve patient satisfaction rates. The study anticipates employing more patients in the future to understand the variability within the patient population.

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Poster Presentation
Orthotics: Spinal

5.14
Orthotic Management of the Spine in Spinal Muscular Atrophy: A Service Evaluation

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BACKGROUND
Thoracolumbar-sacral orthoses (TLSOs) are recommended in the management of children with spinal muscular atrophy (SMA) [1]. Little information is available on the details of orthotic treatment in this group, however.

AIM
This study aimed to define current spinal orthotic care for children with SMA, in a specialist centre.

METHOD
The study was classed as a service evaluation and was registered with the local audit office (reference 2589). Data was reviewed retrospectively. Children seen in the neuromuscular orthotist clinic within a two-month period during 2019 were included.

RESULTS
Diagnoses were SMA 1 (n=10) and SMA 2 (n=6). Mean age at referral was 2.06 years (SD 1.19, median 1.75, range 0.67-4.83). Brooke mobility level ranged from 9 (wheelchair use only) to 7 (walks in knee-ankle-foot orthoses with assistance). TLSOs were all constructed in one piece with an anterior opening and abdominal aperture, using 2-3mm copolymer polypropylene or low-density polyethylene. Casting was performed using a supine frame previously described [2]. Goals were to reduce scoliosis progression and/or improve sitting function. Mean out of TLSO and in-TLSO Cobb angles were 31 degrees and 24.5 degrees respectively (25% correction). TLSOs were prescribed for daytime use only. Mean duration using a TLSO was 2.14 years (SD 2.27, median 0.96, range 0.08-7.83).

DISCUSSION AND CONCLUSION
The current approach to orthotic management of the spine for children with SMA in a single centre is described. Children with SMA appear to tolerate TLSO use with generally positive outcomes. However, the available data to evaluate orthosis wear time and outcomes was limited by the retrospective design. Larger prospective studies would be beneficial to examine clinical outcomes and patient experience related to orthotic management in this group.

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5.15

The Effects of Chêneau Scoliosis Brace made According to the Dr. Rigo Scoliosis Classification in AIS: A Case Report

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BACKGROUND
The treatment method of adolescent idiopathic scoliosis includes surgery, rehabilitation exercise therapy, and the use of a brace. However, there are many different ways to make the brace for the same type of scoliosis, and the effect is very inconsistent. In Taiwan, the most popular brace types for scoliosis such as Boston brace, OMC brace and the brace from European system were few.

AIM
To verify the effects of a Chêneau scoliosis brace made according to the Rigo-System Chêneau scoliosis brace classification in Adolescent Idiopathic Scoliosis.

METHOD
This case is a 12-year-old female. Observed X-rays according to Dr. Rigo scoliosis classification as Thoracolumbar E2 type, other data were Apex T12, Cobb's angle 25, Risser sign 1, Progression Factor=1.8, progressing rate >60%. According to the manufacturing principle of Chêneau's scoliosis brace, the three-point control and anti-rotation control pressure is applied to the left thoracolumbar spine area (T12), the right hip and right axillary at approximately T7 height. The expansion zone is designed in the concave area of the right thoracolumbar spine to make it sufficient for breathing and chest expansion movement. The outpatient follow-up one year later measured the change of Cobb's angle.

RESULTS
After using the scoliosis brace, the Cobb's angle was from 25 degree reduced to 0 degree. Then after one year of continuous wearing of the brace, the Cobb’s angle without wearing the brace showed 0 degree. The correction effect is very obviously.

Initial x- ray	Initial x-ray In-brace	After one year x-ray without brace	Subject with brace
			
fig.1	fig.2	fig.3	fig.4

DISCUSSION AND CONCLUSION
Through this case, it is shown that wearing a scoliosis correction brace can improve the Cobb's angle and prevent further deterioration in the long term. According to Dr. Rigo's classification method as a reference when making Chêneau scoliosis correction brace, the consistency of the brace can be improved, and the performance of the brace has also been improved. Perhaps more different types of scoliosis are needed to confirm the effect of using a corrective brace by Chêneau scoliosis correction brace.

5.16

Effect of Routine Treatment Associated with use of Semi-Rigid and Rigid Lumbosacral Orthoses in Patients with Lumbar Disc Herniation

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BACKGROUND
Lumbar disc herniation is a common condition in adults and can impose a heavy burden on both the individual and society. Many of these patients keep complaining of troublesome symptoms including pain, impaired function, inability to return to work, or any combination thereof. Many patients can be treated effectively by a combination of non-surgical measures such as medication or physiotherapy. Another non-surgical intervention is using lumbosacral orthoses (LSOs) that can be used in addition to physiotherapy.

AIM
The aim of this study was to compare effect of routine treatment (physiotherapy and medication) using semi-rigid and rigid LSOs, and comparison between two types of LSOs on pain, fear of movement, and disability in patients with lumbar disc herniation.

METHOD
In this quasi-experimental study, 27 patients with lumbar disc herniation were assigned in 3 groups including 1: semi-rigid LSO with routine treatment (n: 8), 2: rigid LSOs with routine treatment (n: 8) and 3: routine treatment (n: 11). Before using any therapeutic intervention in each group, pain, disability, and fear of movement of patients was recorded using visual analogue scale, Oswestry questionnaire, and Tampa questionnaire, respectively. Patients in each group then used the allocated interventions for four weeks. After 4 weeks, the patients' pain, disability and fear of movement were recorded for the second time.

RESULTS
Kruskal–Wallis test was utilized for comparison between 3 groups and Wilcoxon signed-rank test for within-group comparison before and after intervention. In comparison between the 3 groups after 4 weeks of using the interventions, no significant difference was observed between them in all variables ($P > 0.05$). In within-group comparison, in the group of routine treatment using semi-rigid LSO, a significant decrease in all 3 parameters of disability, pain and fear of movement was observed after 4 weeks of use of the intervention compared to before ($P < 0.05$). The routine treatment using rigid LSO caused a significant reduction in the two parameters of pain and disability, and the use of routine treatment was significantly reduced only the disability score ($P < 0.05$).

DISCUSSION AND CONCLUSION
Based on the findings, no significant difference was observed between the three therapeutic interventions in the measured parameters. However, the use of physiotherapy and medication along with the use of a semi-rigid LSO improved all parameters compared to before using. Therefore, using both semi-rigid LSO and routine treatments as complementary conservative intervention can lead to better results. Future study is needed to evaluate the long-term effect of these interventions.

5.17

Modular as Effective as Custom-Made. A Matched Case-Control Study of Modular Italian MI-brace vs Very-Rigid Sforzesco Brace in AIS

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BACKGROUND

Recently we developed two innovations for VRB (high-density polyethylene): the “Free Pelvis” (semi-rigid ethylene vinyl acetate) to improve comfort, adaptability and sagittal balance, and the “Adjustable Posterior Closure” for brace adaptability and durability. They allowed introducing a new modular VRB, named MI-brace (Modular Italian brace) (MIB).

AIM

Does modular construction change the efficacy of custom-made Sforzesco very-rigid brace (VRB) for adolescents with high-degree idiopathic scoliosis (AIS)?

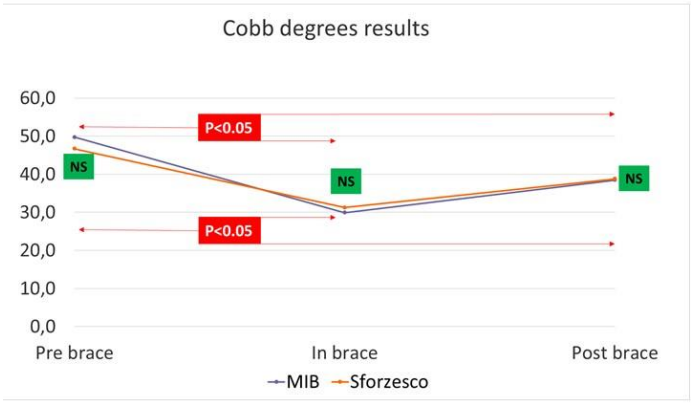
METHOD

Study Design. Matched Case-Control Study. **Participants**. *Inclusion criteria*: AIS, age 10-16, VRB prescribed 23 hours/day, x-rays available, primary curve 36-65°, Angle of Trunk Rotation 7-23°. *Cases* first consecutive MIB. *Controls* consecutive historical VRB matched for sex, weight (range 36/59), height (151/170), BMI (15.5/22.5), menarche age (10/12), Risser (0/4), aesthetics (TRACE 7/12), plumb line distances (S1: -20/20; C7+L3: 10/70), brace use (22/24). **Statistics**. *Linear regression* outcome: short term results - start to first out-of-brace x-ray. *Logistic regression* outcome: improved vs worsened. *Explanatory variable*: brace type.

RESULTS

We included 183 VRB (4% of the initial 4431) and 11 MIB (61%), age 13±1, 47±7° and 50±11° Cobb, respectively. **Baseline characteristics** did not differ. **°Cobb corrections**. *Short-term (5±2 months)* -7.9±5.2 for VRB and -8.1±6.2 for MIB (p= 0.92); *in-brace* -15.8±6.3 and -19.3±6.3, respectively (p=0.07). Type of brace influenced results neither short-term (coeff. -0.19, CI95% -3.3;2.9, R^2=0.0001), nor in-brace (-3.5, CI95% -7.13;0.06, R^2=0.002). Brace type did not affect odds of improvement (OR 0.70, CI95% 0.17;2.8 adj R^2=0.001).

The new MI-brace (Modular Italian brace) and custom-made very-rigid Sforzesco brace have similar radiographic and clinical results.



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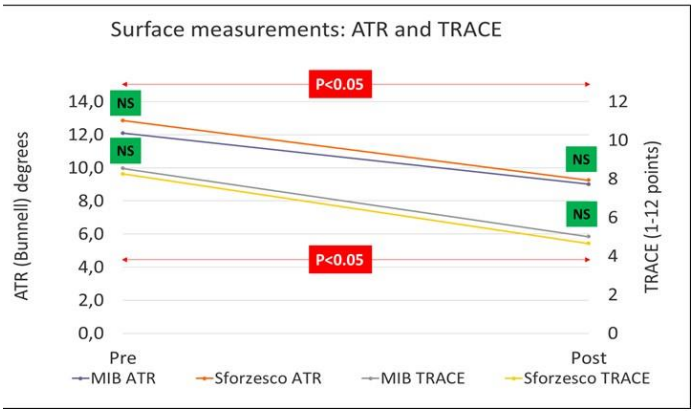

B

DISCUSSION AND CONCLUSION

Clinical and radiographic MIB results are not different from VRB in the short term. A modular construction, based on “Free Pelvis” and “Adjustable Posterior Closure”, does not change the short-term efficacy for AIS achieved by the classical custom-made building of the very-rigid Sforzesco brace.

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5.18

Comparison of Immediate Radiographic Result between Custom-Made Thoracolumbosacral Orthosis with and without Dynamic Thoracic Pad for Adolescent Idiopathic Scoliosis Patient

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BACKGROUND

Spinal Orthosis is the most common treatment for scoliosis. It can be classified into several categories, including a dynamic padding system, which has a moveable strap feature. The lack of evidence-based showing the treatment results can undermine its success. This study featured a dynamic thoracic pad based on the concept of Rosenberger brace combined with a custom-made Boston brace from casting until fitting process.

AIM

To compare the immediate radiographic result between custom-made TLSO with (design 2) and without (design 1) dynamic thoracic pad in AIS patients

METHOD

This study was approved by the Human Research Protection Unit, Faculty of Medicine Siriraj Hospital. The inclusion criteria: AIS male and female; 10–18 years old; 25°–45° Cobb angle; 0–3 Risser sign; flexible curve with all patterns; apical vertebrae from T8 and below. This research began with a case-series study to see the possible treatment outcomes. All processes of design 1 were based on the custom-made Boston brace principles whereas design 2 was modified from design 1. Moreover, fitting of both designs and x-rays were done on the same day.

Table 1. Results of participant 1, 2 and 3

			OBR		IBR (Design 1)		IBR (Design 2)	
			T	L	T	L	T	L
Participant 1	Cobb's angle	Degree	35.00	26.00	24.00	20.00	21.00	18.00
		%			31.53	23.08	40.00	30.77
	Apical translation	mm	21.14	15.51	10.98	10.87	9.26	10.20
		%			48.06	29.90	56.20	34.24
	Coronal decompensation	mm	8.37		1.57		3.23	
		%			81.24		61.41	
Participant 2	Cobb's angle	Degree	32.00	33.00	22.00	16.00	15.00	9.00
		%			31.25	51.52	53.13	72.73
	Apical translation	mm	8.00	12.50	1.94	9.97	3.06	7.15
		%			75.75	20.24	61.75	42.80
	Coronal decompensation	mm	20.00		13.61		16.84	
		%			31.95		15.75	
Participant 3	Cobb's angle	Degree	31.00	29.00	25.00	28.00	22.00	26.00
		%			19.35	3.45	29.03	10.34
	Apical translation	mm	16.05	21.15	9.46	27.42	8.17	22.61
		%			41.06	-29.65	49.10	-6.90
	Coronal decompensation	mm	10.08		19.43		3.01	
		%			-92.76		70.14	

Note. OBR = Out-brace radiographic, IBR = In-brace radiographic, T = Thoracic. L = Lumbar. % = Reduction percentage.

RESULTS

Three AIS participants were fit with TLSO designs 1 and 2 and an in-brace x-ray was taken immediately. Cobb angle, apical translation, and coronal decompensation were measured and compared with the most recent out-brace x-ray reporting as a reduction percentage. TLSO design 2 reported better results in Cobb angle reduction at thoracic and lumbar curves in all participants. As well as the apical translation reduction, it presented better results for participants 1 and 3 at thoracic, and lumbar for participants 1 and 2. Whereas coronal decompensation reduction was better in design 1 as presented in participants 1 and 2.

DISCUSSION AND CONCLUSION

Both designs showed improvement in all outcomes. TLSO design 2 showed better results in Cobb angle and apical translation reduction compared with design 1. However, it could not conclude the final treatment outcomes because it only focused on the immediate results in 3 patients. Therefore, larger participants are highly recommended for further study and is supposed to include patients' compliance and the quality of life in the long-term.

ACKNOWLEDGEMENTS: Thanks, SSPO and Faculty of Medicine Siriraj Hospital for providing all resources. Thanks to our participants who had been cooperative.

5.19

Development and Evaluation of New Custom Made Roi-Et Plastic Minerva Brace for Cervical Spine Injuries

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BACKGROUND

Plaster Minerva cast was the most common orthotic treatment in Roi-Et hospital for C-spine injuries (CSIs), but it has various disadvantages and complications which are heavy, cumbersome plaster, unhygienic due to sweat under the plaster jacket, skin breakdown and easy for skin irritation. Three version of custom-made Roi-Et plastic Minerva brace were created and developed from plaster Minerva cast.

AIM

to develop Custom Made Roi-Et Plastic Minerva Brace to provide great rigid immobilization/ reduce cost for government insurance cover in all CSI patients, reduce time for fabrication, avoid complications of plaster Minerva cast and easy to don while patient supine.

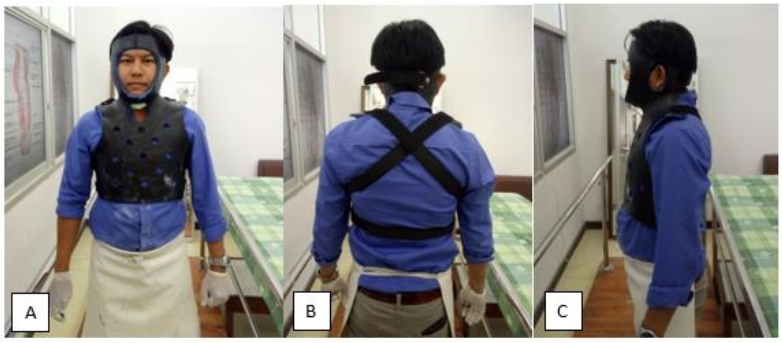
METHOD

1. Design the Custom-Made Roi-Et Plastic Minerva Brace that easier to don while patient lying in supine which is one piece of plastic anterior shell.
2. Casting
3. Rectification
4. Fabrication
5. Fitting

1. The position of patient should be in supine and neutral position.
2. Patient should wear the stockinet or shirt before donning the Minerva orthosis.
3. Open the opening area at the proximal posterior of device, insert the device to patient neck and slight upward to the exactly position.
4. Tighten the posterior band with strap of the opposite shoulder, tighten distal strap and head strap.

RESULTS

The plastic Minerva brace can restrict motion of head by measurement from the landmark. It shown that rotation, flexion, and lateral flexion, participant can perform less than 0.5 centimetre while using plastic Minerva brace.



The picture of custom-made Roi-Et plastic Minerva brace

A. anterior view B. Posterior view C. Lateral view

DISCUSSION AND CONCLUSION

Custom Made Roi-Et Plastic Minerva Brace can provide great rigid immobilization/reduce cost for government insurance cover in all CSI patients, reduce time for fabrication, avoid the complications of plaster cast, easy to don while patient supine. The device can immobilize the c-spine, patient was satisfied and it can provide lighter weight and comfortable. So this version of Minerva brace can be alternative choice to treat CSIs instead of plaster Minerva cast and doctor satisfied to prescribe for CSI patients.

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Poster Presentation
Orthotics: Upper Limb

5.20
Are Hand Splints Effective in Rhizarthrosis? A Review

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BACKGROUND
Trapeziometacarpal arthritis or rhizarthrosis is a highly prevalent chronic condition that causes pain, limits hand function, and interferes with health-related quality of life.

There are many conservative treatments available including drugs, physiotherapy and use of orthotic devices. Few of these methods have been really evaluated. We propose a critical review of the literature on orthotic treatment in rhizarthrosis.

AIM
To perform a systematic review on the effectiveness of hand splints as a conservative management in rhizarthrosis

METHOD
A PubMed, PEDdro and Medline database research performed with the key terms: “Hand splint”, “Rhizarthrosis” “Trapeziometacarpal arthritis”, “Conservative management” in the last 20 years written in English. We retrieved all randomized controlled trials (RCT) comparing the use of splints against other approaches.

RESULTS
Eleven studies were selected: 4 comparing splints to a control and 7 to another splint. There was fair evidence for the effectiveness of splinting to relieve pain and improve function. In the medium-term (3-12 months), low quality evidence showed that splints cause a moderate to large reduction in pain and small to moderate improvement in function. There was no clear evidence of the superiority of one type of splint over another for pain relief, comfort, or function.

DISCUSSION AND CONCLUSION
The orthosis for rhizarthrosis presents low-quality evidence for reducing pain in the long term and moderate evidence for an increase in function in the long term. Since imprecision and inconsistency of the data were aspects which influenced the quality of the evidence, future studies with larger samples and standardized data are needed.

Poster Presentation
Prosthetics: Lower Limb Transfemoral

5.21

Thirteen Years of Health Economic Evaluations for Microprocessor-Controlled Knee Joints: A Review (2008 to 2021)

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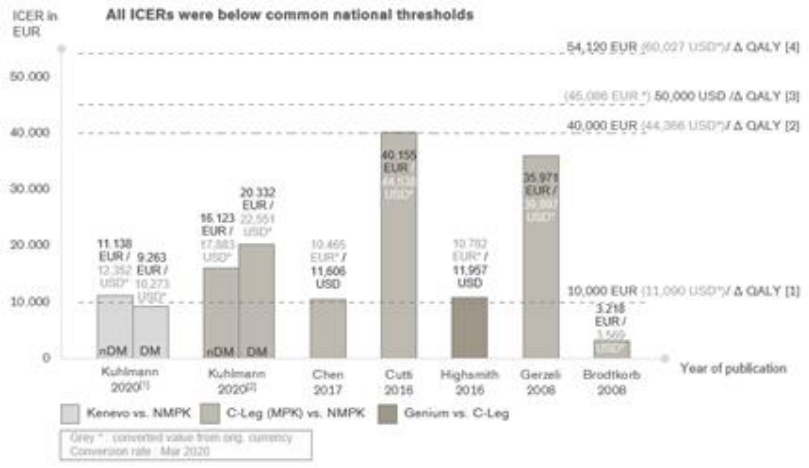
BACKGROUND
Since health-economics research was introduced in prosthetics and orthotics by assessing microprocessor-controlled knees (MPKs), the quality of methodology, models and input data has steadily evolved. Today, with considerably improved evidence on the clinical effectiveness of MPKs, it is warranted to corroborate previous preliminary health-economic findings that have supported the assumption that MPKs may be considered standard of care in individuals with transfemoral amputations by high-quality health-economic research.

AIM
To evaluate the relevant health-economic effectiveness and affordability of MPKs in various patient cohorts.

METHOD
A literature review and analysis of publications on MPK interventions and comparators, patient cohorts, methodology, model inputs (databases used), and relevance of the health-economic results was performed using the search terms microprocessor-controlled knee, C-Leg/Kenevo/Genium, cost-effectiveness/utility, (health)-economic, budget impact, transfemoral/above knee amputation in PubMed, Cochrane Library and Google Scholar from the year 2008-2021 in March 2021. 20 publications were identified and 12 were excluded. All 8 health-economic studies that evaluated the economics of MPKs (study intervention: 4 C-Leg[2,4,5,6], 2 MPK based on C-Leg data[3,7], 1 Genium[8] and 1 Kenevo[1], comparator NMPK) were analysed using the CHEER-checklist[9] for this review.

RESULTS
Four studies used a cohort-level Markov-model[1,2,3,6], 5 studies assumed the payer-perspective[1,2,4,6,8], 2 studies[3,7] the societal-perspective and one study both perspectives[5]. Data sources were study cohorts[4,5,6,7,8], health insurance, other official national databases[1,2,3] and actual data input for health care costs[1,2,3]. The incremental cost-effectiveness ratios (ICER)/QALY gained ranged from EUR3,218 to EUR40,155* (fig1). Cost-effectiveness compared to NMPKs was demonstrated in 3 studies (deterministic and probabilistic sensitivity analyses)[1,2,3], with 2 of them also performing a budget-impact-analysis[1,2]. Over a 5-year observation period, use of the C-Leg would incur additional expenditures of EUR53m* for patients without DM and EUR45m* for those with DM in Germany[2]. If all new prosthesis-users ≥65 years in Sweden received a MPK (Kenevo) and 50% of prevalent-NMPK users were re-fitted with a MPK, additional expenditures of EUR1.72m* would incur[1].



DISCUSSION AND CONCLUSION
Individuals using C-Leg / MPKs do benefit from improved QoL, QALY gain and safety. This benefit was also demonstrated for individuals >65 years of age and ≥6 months post-amputation using Kenevo. Cost-effectiveness of MPKs along with affordability has been clearly demonstrated and supports the clinical relevance for the consideration as standard of care.

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5.22
Polycentric Exoprosthetic Knee Joints – Extent of Shortening during Swing Phase

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BACKGROUND
Tripping is a safety risk for amputees and it is mainly affected by reduced ground clearance during swing phase. An often-assumed advantage of polycentric knee joints compared to monocentric concepts is the improved ground clearance during swing phase due to the geometric shortening of the lower leg segment (LLS)[1,2,3]. Based on this statement safety benefits for above knee-amputees due to reduced danger of stumbling are discussed commonly for the entire group of polycentric knee joints.

AIM
To investigate whether polycentric knee joints considerably improve ground clearance and to evaluate the influence of prosthetic alignment on the extent of ground clearance.

METHOD
Eleven polycentric and 2 monocentric knee joints were attached to a rigid, stationary testing device which allows for a step-less adjustment of the hip flexion angle. Prosthetic components were mounted at the same height. The anterior-posterior position was in accordance with the manufacturer's alignment recommendations. Shortening of the LLS and the resulting ground clearance during knee flexion were measured at four hip flexion angles (15°, 20°, 25°, 30°) with an optoelectronic 12-camera motion capture system (Vicon, UK). A setup validation was conducted. The authors assume an accuracy of ±1.1 mm for the investigated parameters.

RESULTS
Shortening of up to 14.7 mm at the instance of minimal ground clearance during swing phase was measured. One knee joint elongated by 4.4 mm. Measurements of the ground clearance demonstrated differences up to 25.4 mm. One monocentric knee joint provided more ground clearance when compared to 8 of the polycentric knee joints investigated. A comparison of different alignment methods with regards to toe clearance was conducted for one monocentric and one polycentric knee joint and showed differences up to 8.2 mm.

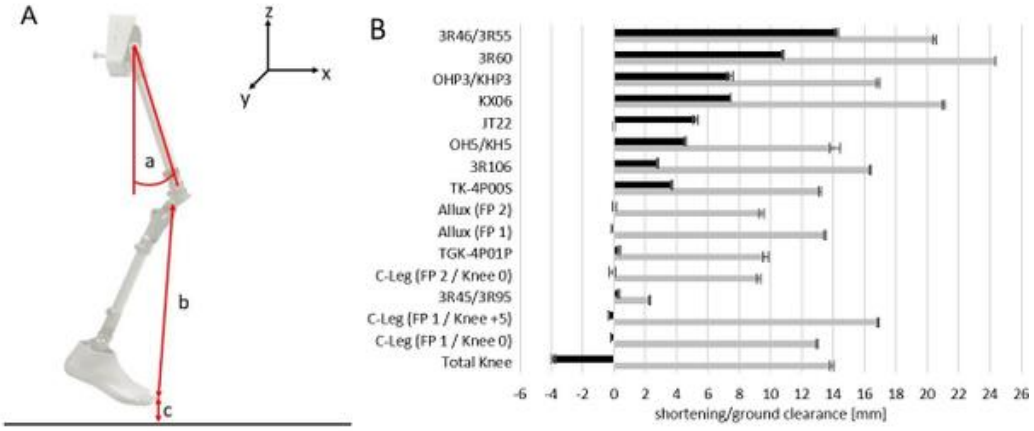

Figure 1. (A) Schematic illustration of the experimental setup, hip flexion angle (a), length of the lower leg segment (b), minimum ground clearance (c); (B) Shortening of the lower leg segment (black) and ground clearance (grey) at 25° hip flexion.

DISCUSSION AND CONCLUSION
The results showed, that only some polycentric knee joints shorten appreciably at the instant when a stumble might occur. Thus, the previously stated functional advantage of greater ground clearance for patients must be reconsidered. A slightly more anterior position of the knee joint or a more posterior position of the foot can compensate for or even exceed the extent of the geometric shortening of the shank of some polycentric knee joints.

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5.23
Assisting Sit and Stand Transitions with an Energy-Harvesting Knee Prosthesis

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BACKGROUND
Geriatric individuals with transfemoral limb loss can find sit-to-stand-to-sit transitions challenging due to a loss of prosthetic side knee and ankle musculature [1,2,3]. When rising from a chair, these individuals heavily rely on their contralateral limb and upper limb strength to lift their body weight [2,3,4]. These users, who often have marginal and declining strength, could retain their independence if a prosthetic knee assisted with sit-to-stand-to-sit transitions, a task that is fundamental for normal activities of daily living [5].

AIM
The purpose of this pilot research was to evaluate an experimental energy-harvesting knee prosthesis (called Assist-Knee) in geriatric individuals with transfemoral limb loss during sit-to-stand (STAND) and stand-to-sit (SIT) transitions.

METHOD
Three transfemoral prosthesis users completed STAND and SIT transitions with an experimental knee prosthesis in an IRB-approved study. The Assist-Knee prosthesis was designed to store energy when loaded during SIT and to return energy during STAND. The participants were trained to use Assist-Knee. Three conditions were tested: habitual and two Assist-Knee settings. Participants completed the following sequence for each condition: start in upright standing position, SIT, remain seated for approximately three seconds, STAND, and end in upright standing position. Motion capture and Smart Pyramid transducer anterior-posterior (A/P) prosthetic moments (Orthocare Innovations, Edmonds, WA) were recorded for all conditions.

RESULTS
In general, all three participants adapted to using Assist-Knee and were able to complete SIT and STAND transitions with the prototype. Two of the three participants rated Assist-Knee very safe for SIT and STAND. SIT and STAND times with Assist-Knee were longer than with the habitually used prosthesis. Assist-Knee enabled participants to place more weight on the prosthetic side than typically done with their habitually used prosthesis. Compared to the habitually used prosthesis, Assist-Knee reduced the average contralateral limb knee joint moment during STAND and also changed the A/P moment generated with Assist-Knee.

DISCUSSION AND CONCLUSION
The user testing elucidated several design improvements that can optimize energy release and ergonomic user interfaces. The increased time to SIT with Assist-Knee was considered a positive outcome. During SIT, participants heavily relied on their contralateral limb and often “collapsed” onto the chair with their habitually used prostheses. The pilot clinical test demonstrated that Assist-Knee can safely store energy during SIT and release that stored energy during STAND to provide a small assistive “boost” to the user.

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5.24

Extension Prosthesis with Free Knee joint in a Complicated Case with Proximal Femoral Focal Deficiency

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BACKGROUND

A 12-year-old female child presented with congenital proximal focal femoral deficiency right limb, absence of 4th and 5th toes, ankle planter flexion contracture, and fibular hemimelia. She went through multiple surgeries for elongation of femur, the family refused ankle rotational surgery or amputation. Child was using nine extension prostheses with static knee for the last seven years, and presented with many gait deviations. She attended to replace the device with the aim of not being seen as disabled among her colleagues in school.

AIM

As she was growing in her adolescent period, the aim was to avoid being seen as disabled. Objective was to improve walking and mobility and to be able to bend the leg when she sits in her school desk.

METHOD

There were limited components available for a child size and P&O tried her best using the available material. An extension prosthesis with knee joint was produced: EVA for soft liner and lamination for hard parts, straps for anterior shell, direct adapter, shifting adapter, single axis knee joint, tube, foot adapter and foot. She received gait-training sessions to ensure safety, proper training and to collect user feedback on each session. OPUS Lower Extremity (LE) Functional Status Measure was used to compare both the old static device and the new dynamic device. To analyse, OPUS table was used to convert raw score to Rasch Measure (0 – 100 scale).

RESULTS

She was able to sit and stand independently. Walking speed was close to normal, able to walk with free knee joint, acceptable gait cycle and controlled knee joint, however with slightly remaining lateral trunk bending. Right knee level was 10 cm lower than left knee, however, wasn't obvious especially in sitting. She expressed her happiness and confidence while sitting in her school desk as not having to leave her leg extended like old device.

OPUS LE functional score of old device was 46/80 (=51.21%) while the score was improved to 64/80 (=63.67%) with the new device based on OPUS table of measure.

Follow-up schedule was set every 2 months. Her interaction with school colleagues has improved with better quality of life achieved.

DISCUSSION AND CONCLUSION

Following up development of children and their preferences, especially in early adolescent stage, is very important and should be continuous to better tackle any development as children grow very quickly.

Having to deal with complex cases is sometimes a limiting factor for intervention and we should respect and adapt ourselves to respond to user preferences. Efforts should be always made to work on comfortability and appearance of device as well as functionality.

5.25
How Heel Rise Control Affects Amputee Biomechanics

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BACKGROUND
People's gait parameters differ depending on their walking speed [1] and walking gradients [2]. Without muscular control at the knee and ankle, transfemoral amputees are reliant on the intelligence of the microprocessor control (MPC) of their prostheses to perform these accommodations. A new MPC algorithm has been developed to better adapt to inclines and sudden changes in gait speed.

AIM
To investigate how controlling the degree of prosthetic heel rise can affect biomechanics during different walking activities.

METHOD
A cohort of K3 transfemoral amputees (n=4) volunteered for this study. Participants were fitted with a Linx v2 integrated prosthetic limb. Motion capture data were collected overground (where the participants were asked to accelerate instantaneously from slow speed to fast speed) and on a 5° inclined treadmill (at constant speed). Both tests were performed with the MPC switched on and off, in a randomized order. When accelerating, MPC limits heel rise. On the incline, MPC aims to provide reduced resistance to ankle rollover, greater energy return from the heel spring and increased heel rise.

For the inclined tests, participants wore a pulse monitor as an indicator of perceived effort.

RESULTS
During the acceleration tests, with MPC on, heel rise and swing phase knee flexion were reduced. As a result, the prosthetic knee reached full extension earlier in the gait cycle. Participants described the MPC off condition as having to "wait for the leg to catch up". These changes also improved gait symmetry.

During the inclined tests, the reverse affect was observed with MPC on; knee flexion and heel rise both increased. As a result, minimum toe clearance increased by approximately 8%. Within individuals, pulse rates were lower with MPC on.

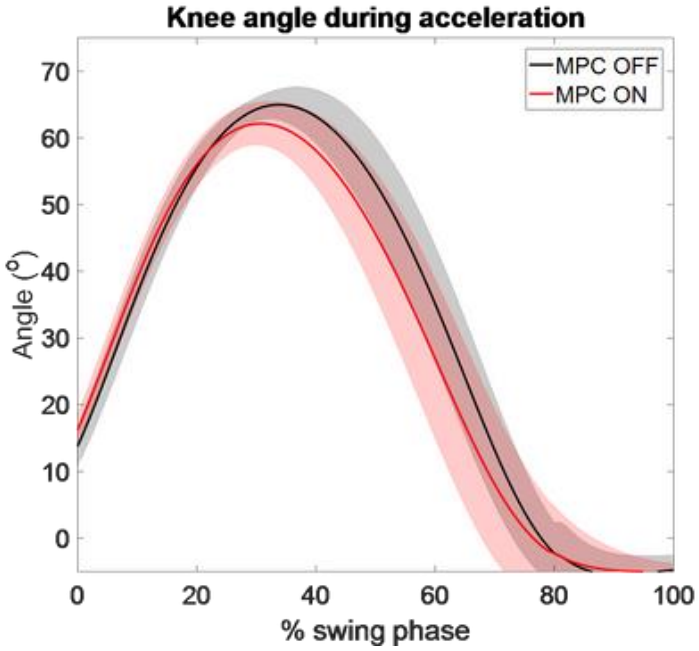

Figure 1: Mean (+/- SD) knee flexion angle during swing phase when accelerating with MPC on (red) and off (black)

DISCUSSION AND CONCLUSION
The findings of this work suggest heel rise control may play an important role in prosthetic knee mechanics, which can have a compounding effect on the biomechanics of the rest of the body. Reducing kinematic compensations can help to improve walking energy efficiency [3].

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5.26
FEM-Simulation in AK Prosthetics - Volume Management at it`s Best

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BACKGROUND
The measurement of an AK-stump in the field of the transfemoral prosthetics is a subjective process due to the mostly used technology. The circumference of the residual limb, the length of the residual limb and the reference lines cannot be recorded in a conventional manner with a tape measure and ruler. Based on this data, the stump models are modified and a prosthesis socket is constructed. The 3D scanning technology offers new possibilities to further expand the digital process chain.

AIM
A qualitative analytic tool for evaluating the prosthetic socket fit in the area of the volume stump and thus an objective statement to optimize the volume-fit of transfemoral prosthesis sockets in a 3 dimensional manner.

METHOD
The transfemoral stump is recorded in its entirety via a 3D scan. This is accompanied by certain landmarks for orientation and setting up the socket simulation. The stump, socket model, a reference line and biometric data are entered into the processing program. The simulation is based on a finite element method. The required calculation resources are made available to high-performance computers via a cloud service.

RESULTS
The use of simulation-supported prosthetic socket adaptation offers possibilities for objectification and quality assurance of prosthetic sockets. Furthermore, a standard can be created through the socket simulation, which considers the high individuality of the amputees for the prosthesis socket adaptation.

DISCUSSION AND CONCLUSION
The possibilities of simulation in orthopaedic technology are only just being grasped and are just in the beginning. Simulation methods are developing, material parameters are increasingly being better fitted, and the background is being worked out. The simulation software is increasingly finding its way into our everyday lives and is developing into an incessant analysis tool.

5.27
Bone-Anchored Prosthesis – A Solution for each TF-Amputee?

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BACKGROUND
Bone anchorage of an artificial limb has been proven to be an alternative intervention for amputees when prosthesis use is seriously reduced because of stump problems or socket discomfort. Could these indications be extended? Presently, that topic is frequently discussed. Little is known about which potential the optimum use provides with respect to recover a normal gait pattern, also compared with up-to-date socket prosthesis.

AIM
Does bone anchorage of an artificial limb permit recovering a normal gait pattern? Is every lower limb amputee a good candidate for this type of fitting?

METHOD
Parameter: If the function of lower limbs possesses no limitations the GRF of both legs are identical. For unilateral impaired leg function the GRF is expected to be reduced. Thus, GRF seems to be a suitable parameter measuring the force transmission capacity of leg.
Measurement: Instrumented gait analysis (VICON-cameras, Kistler force plates)
Subjects: 15 healthy persons (NA), 9 unilateral TF-amputated persons with bone fixed prostheses (TF-Osseo), 9 unilateral TF-amputated persons with socket prostheses (TF-Socket) und 18 patients with unilateral hip replacement (HTEP).
All participants walk several times at comfortable walking speed (SSWS), slower and faster than SSWS.

RESULTS
The group TF-Osseo was measured at three periods (preoperative, one and two years postoperative). The participants of group NA, TF-socket and HTEP (8.8 month postoperative) underwent once gait analysis. GRF of TF-Osteo was identical for period one and two years postoperative, preoperative similar to TF-Socket. The speed dependency of GRF is significant different between the groups (Figure 1 middle and right). The highest contralateral forces were measured for TF-Osseo. The group HTEP shows values which are similar of NA (Fig.1 left).

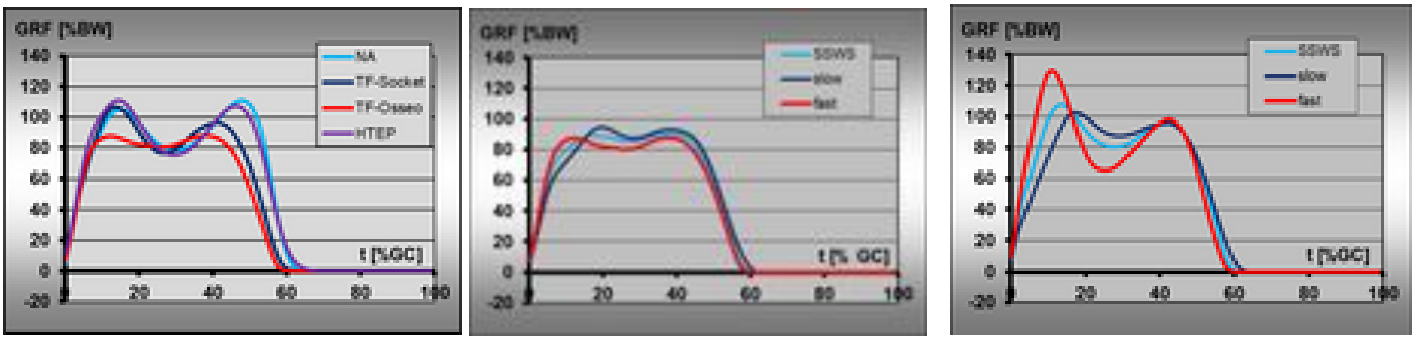

Figure 1: Mean vertical ground reaction force during gait cycle (GC). Left: Group mean at app. 1,3 m/s, middle: TF-Osseo one year postoperative, right: TF-Socket

DISCUSSION AND CONCLUSION
The vertical GRF seems to be a sensitive parameter to assess the force transmission capacity of lower limb during walking. The results reveal that the force transmission efficiency is almost normal for patients with hip replacements, reduced for TF-Socket and lowest for TF-Osseo. Therefore, the bone anchored TF-prostheses are an excellent alternative for patients with stump problems but offer not to be the gold standard for any TF-amputee.

Poster Presentation
Prosthetics: Lower Limb Transtibial

5.28
Visualisation of In-socket Residual Bone Movement using B-mode Ultrasound in a Patient with a Transtibial Prosthesis

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BACKGROUND
Quality of prosthetic socket fit depends on force transmissions between skeletal system and prosthetic socket through soft tissue layers. In clinical practice, it remains challenging to create an “optimal” socket fit that allows transmission of external forces with minimal strain on the soft tissues of the stump. Currently, this is a subjective process without availability of objective information on residual limb movement within the socket. Ultrasound could potentially be useful given its capabilities of visualizing tissue deformation in vivo (1).

AIM
The aim of this study was to develop a method to apply ultrasound to track the in-socket residual bone movement for transtibial amputees.

METHOD
A proof-of-concept study on a single transtibial amputee, fitted with a silicone-gel liner and sub-atmospheric pressure socket was conducted. The ultrasound probe was connected to the socket in a seated position, a 3D printed clamp was installed to hold the ultrasound probe in place during measurements (Figure 1). The residual limb movement was recorded during forwards, backwards and sideways in-place stepping.

Figure 1: Position of the ultrasound connector and ultrasound image of the pre-pilot measurement.
The left and middle image show how the probe is connected to the socket. The two right pictures show the image produced by the ultrasound system, measured through the socket, liner and skin materials. In the lower right picture different tissue layers are highlighted: 1. Socket, 2. Liner gel-sock, 3. DUO liner, 4. Skin, 5. Tibial crest

RESULTS
B-mode ultrasound allowed visualization of residual bone movement through a sub-atmospheric prosthetic socket during stepping. Bone movements relative to the socket were recorded in video format and quantified using image tracking software (Figure 1).

DISCUSSION AND CONCLUSION
These preliminary results show the potential of the measurement technique. Currently, a study is prepared to assess reliability and sensitivity. Ultimately, residual limb movement will be monitored in amputees during gait with different prosthetic alignments.

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5.29
Musculoskeletal Pain with use of a Powered Prosthetic Ankle-Foot Component

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BACKGROUND
Lower limb amputees often ambulate with compensatory gait patterns resulting in increased loading of the sound limb [1]. Powered ankle-foot components providing active push-off were shown to result in decreased sound knee loading [2, 3]. This study aimed to corroborate anecdotal patient feedback that use of a powered foot may decrease knee and back pain compared to passive feet.

AIM
The aim of the study was to investigate the impact of the use of a powered prosthetic ankle-foot component on sound and residual knee pain, low-back pain and pain-related restrictions of function compared to passive prosthetic feet.

METHOD
250 subjects fitted with a powered ankle-foot component (Empower) in the past were invited to participate in an IRB-approved online survey. Three 0-10 numerical pain rating scales (NPRS) for sound knee, amputated side knee, and low-back pain, the Socket Comfort Score (SCS), the ADL domain of the Knee Injury and Osteoarthritis Outcomes Score (KOOS), and the Oswestry Disability Index (ODI) were assessed for the currently and the previously used prosthetic foot. Statistical tests were run for original ratings and after 10% adjustment for recall bias for foot types (powered or passive) that patients used in the past but currently do not.

RESULTS
The responses of 57 individuals, all male, with unilateral transtibial amputation and a mean age of 53.5±13.0 years were analysed. Aetiologies were 75% trauma, 16% dysvascular and 9% other. Forty-one subjects (71.9%) identified as Current Powered Ankle-Foot users.

Significantly lower pain ratings with the powered ankle-foot were found for sound limb knee pain ($p=.001/.001$), amputated limb knee pain ($p=.005/.016$), as well as low-back pain ($p<.001/<.001$) for both the original and recall-adjusted ratings. The differences in medians reached or exceeded the minimal clinically important difference (MCID) of 1 point for both the original and recall-adjusted ratings. Significantly more subjects reported no sound knee ($p=.004$) or low-back pain ($p=.012$), respectively, with the powered ankle-foot. Original and recall-adjusted KOOS-ADL and ODI scores were significantly better when using a powered ankle-foot as compared to the use of a passive foot ($p<0.001$ for all).

DISCUSSION AND CONCLUSION
Use of a powered prosthetic ankle-foot component may contribute to alleviate sound and residual knee pain, low-back pain and pain-related restrictions in physical function in individuals with transtibial amputation by reducing collision work in the leading limb [4] and improving more symmetric limb and trunk muscle activation and loading [5] compared to passive prosthetic feet with reduced push-off. To our knowledge, this is the first study that investigated the direct impact of a prosthetic component on musculoskeletal pain.

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5.30

The Reliability of Low-Cost Photogrammetry for Measuring Amputee Residua

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BACKGROUND

Three-dimensional scanning technologies have been used in the field of prosthetics with promising results, scanning residual limbs, but with high cost [1]. Photogrammetry provides low-cost 3D scanning with the use of any handheld camera [2]. However, low-cost cameras (e.g., smartphone camera) require validation assessing their ability to provide reliable outcomes in terms of shape and volumes.

AIM

The aim of this study was to assess the reliability of two common low-cost camera systems for assessing shape and volume of different objects including a residual limb model.

METHOD

Two experiments were carried out to test the reliability of photogrammetry. The first used 4 wooden objects of known volume to examine how the number of images affected reconstruction accuracy and reliability, using a Sony-α5000 camera and an LG-G5 smartphone. The number of photographs for the 3 tests were 20, 36, and 72. The process was repeated twice (with and without additional texture information). Test-retest reliability was determined by repeating the process five days later. The second used the same protocol to determine the effect of image numbers, surface texture, and test-retest reliability, using 3 different amputee-residuum-models. An ArtecEva 3D-scanner was used as a gold-standard to determine the actual volume.

RESULTS

Bland-Altman analysis was performed to quantify the agreement between methods. The results, summarized in Table 1 showed that the best outcomes were obtained for the Sony Camera with 72 images.

Camera	Images	Mean Difference (Bias) (ml)	Random Error (SD of Bias)	95% LoA	
Sony	72	8.9	34.52	-76.56	58.76
Sony	36	24.03	26.86	-28.61	76.67
Sony	20	17.93	45.91	-72.04	107.91
LG	72	38.57	37.65	-35.23	112.37
LG	36	20.93	82.98	-141.72	183.72
LG	20	69.6	167.74	-259.17	398.37

DISCUSSION AND CONCLUSION

The photogrammetry technique has showed promising results with the best outcomes obtained when taking 72 images with a Sony Camera. Furthermore, 3D models produced by the smartphone camera have on average no more than 0.204% of random error. Photogrammetry may provide a viable low-cost alternative to limb volume estimation Future investigations, should aim to investigate the photogrammetry outcomes on real participants.

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5.31

Injurious Falls in Transtibial Prosthesis Users are Significantly Associated with Fatigue due to Activity at the Time of a Fall

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BACKGROUND

Between 18 and 26 percent of lower limb prosthesis users report one or more injurious falls a year (1-4). Injurious falls in lower limb prosthesis users are associated with significant financial costs and activity restrictions (3-5). To reduce injurious falls, it is important to identify risk factors amenable to treatment. However, most risk factors associated with injurious falls in lower limb prosthesis users identified in the literature to-date are non-modifiable (e.g., sex, race).

AIM

The aim of this study was to identify factors associated with increased risk for injurious falls in unilateral transtibial prosthesis users

METHOD

Fall frequency, circumstance, and consequence data were collected prospectively from 45 unilateral transtibial prosthesis users for 6-months via monthly telephone calls. Demographic, amputation, health, balance, and mobility-related data were collected at baseline, and assessed as potential risk factors. Relative risk (RR) ratios with 95% confidence intervals (95%CI) were computed to identify factors associated with an increased risk for injurious falls. Chi-squared tests were run to determine whether the risk associated with each factor was statistically significant ($p<.05$).

RESULTS

Forty total falls were reported by 21 participants over 6 months. Eleven participants reported a total of 22 injurious falls. Only four variables were found to be significantly associated with an increased risk for injurious falls: age over 65, being fatigued due to activity, walking with a narrow base of support, and being in a crowded area at the time of the fall (Figure 1). Risk of injury was greatest for "being fatigued due to activity," which increased the risk of injury by nearly 2.5 times (RR=2.45, 95% CI: 1.31-3.79, p=.003). Surprisingly, a number of amputation (e.g., aetiology, time since), health (e.g., number of co-morbidities), balance (e.g., history of falls, low balance confidence), and mobility-related (e.g., K-level) variables were not significantly associated with a greater risk of injurious falls.

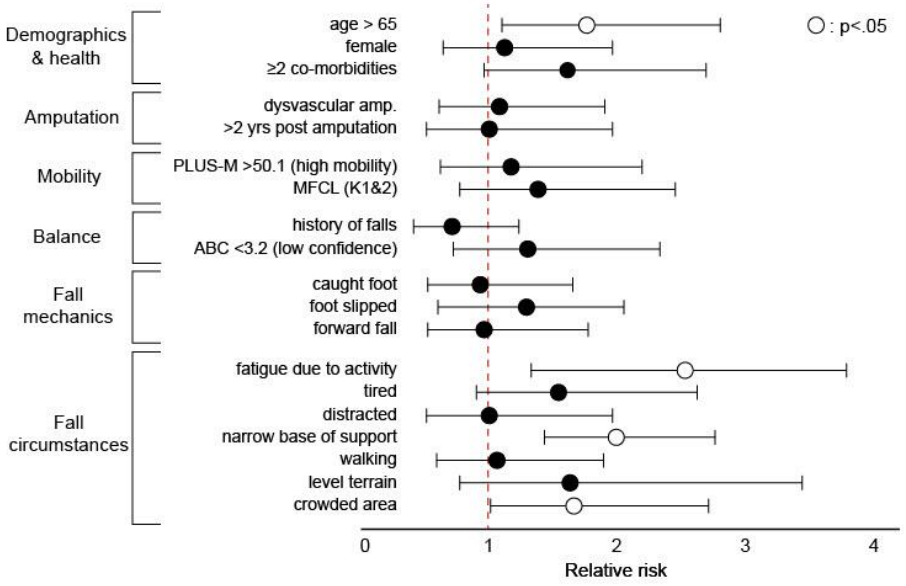

Figure 1. Relative risk for factors associated with injurious falls in unilateral transtibial prosthesis users. ABC: Activities-specific Balance Confidence scale; MFLC: Medicare Functional Classification Level; PLUS-M: Prosthetic Limb User Survey of Mobility

DISCUSSION AND CONCLUSION

This is the first study to identify potentially-modifiable risk factors associated with injurious falls in transtibial prosthesis users. Our results suggest that activity-related fatigue may serve as a practical and promising target for developing tests that assess fall risk and/or interventions that reduce fatigability and associated fall-related injuries. However, additional research involving transfemoral prosthesis users, multivariate regression modelling, and objective measurement of fatigability in lower limb prosthesis users is required.

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5.33

Effects of Unity Suspension System on Minimum Swing Toe Clearance in People with Transtibial Amputation

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BACKGROUND

The vertical distance between the swinging foot's toe region and the ground is defined as minimum swing toe clearance (MSTC) and is a critical gait parameter linked to tripping risk [1, 2]. The risk of tripping in people with amputation is greater than able-bodied individuals due to reduced toe clearance during swing. The effects of Össur's Unity suspension system on MSTC has not been studied yet.

AIM

Evaluate the effects of Össur's Unity suspension system on MSTC during gait across multiple simulated real-world walking scenarios and to compare MSTC with able-bodied individuals.

METHOD

A convenience sample of 12 active people with transtibial amputation who used their prosthesis daily and could walk without walking aids were fitted with the Unity system. A Pro-flex XC foot and a Seal-In V liner were selected for each participant. The participant's mean height was 178.3 (SD=6.4) cm, weight was 90.6 (SD=16.4) kg, age was 57.2 (SD=15.3) years, and time since amputation was 13.1 (SD=20.0) years. After one month accommodation period, the person walked with active (ON) or inactive vacuum (OFF) in a CAREN-Extended virtual reality system, across multiple simulated real-world scenarios. MSTC, ankle, hip, and knee, data were compared with a group of 12 able-bodied individuals.

RESULTS

Descriptive statistics showed that MSTC, knee, and hip angles were greater on the prosthetic side (ON and OFF) than the intact side. MSTC and knee angle were greater on the prosthetic side than able-bodied individuals; however, hip flexion angle on the prosthetic side was 17% smaller than the control group. Unlike the control group, MSTC was not significantly different between level walking and other walking conditions, with active and inactive vacuum suspension. Lowest swing toe clearance for both control and the amputee groups occurred when the limb was at the top of a side-slope. Maximum MSTC and knee angle occurred during down slope for both vacuum conditions. However, in the able-bodied group, maximum MSTC was during rocky and knee angle was during up slope walking.

DISCUSSION AND CONCLUSION

Effective prosthetic suspension system and prosthetic foot could improve MSTC and might decrease the risk of tripping and falling. The results of this study showed that active people with transtibial amputation could have appropriate MSTC during gait, when using the Unity suspension system and Pro-Flex XC foot. The likelihood of inappropriate foot contact on side-slope ground might be greater than other walking conditions for both able-bodied and amputees group, possibly leading to stumbling or falling

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5.34

Enrichment of Wearable Sensor Data from Individuals with Lower Limb Amputation in a Free-Living Setting

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BACKGROUND

Objective physical activity monitoring of lower limb amputees can be achieved using wearable sensors; however the literature has shown that simplistic objective monitoring (for instance, measuring step count or energy expenditure) is overwhelmingly favoured [1]. For a more detailed analysis of activity, the implementation of machine learning algorithms to recognize wider varieties of activity is a logical solution. Currently, no research has attempted to perform HAR with an amputee population using an unsupervised learning approach.

AIM

To provide clinically useful information for healthcare professionals specialising in lower limb amputee rehabilitation by developing a robust unsupervised classification system that can recognize different activities and walking terrains covered by lower limb amputees.

METHOD

The following methodology was given ethical approval by the University of Strathclyde's Ethics Committee. A combination of amputee volunteers with no known comorbidities and healthy volunteers with no known gait impairments were recruited for the study. The participants were instructed to utilize an IMU and to record themselves with a chest-mounted camera while going on a walk on a variety of terrains in the local vicinity of their homes. The collected IMU data was used to train an unsupervised classification system to recognize walking activities and terrains, with the annotated data from the camera providing validation to the performance of the classifier.

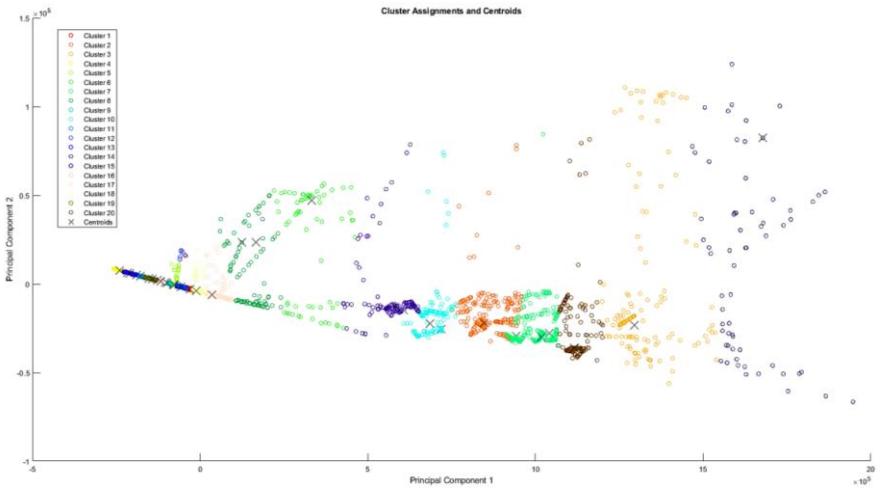

Figure 1 - Clusters of the dataset (n = 20) in the Principal Component space, attained via K-Means Clustering

RESULTS

Twelve participants were recruited for the study. This demographic was comprised of 8 healthy individuals, 3 transtibial amputees and 1 bilateral amputee. The development of the classification algorithm is an ongoing process. Principal component analysis is applied to reduce the dimensionality of the feature set to 2 dimensions. The K-Means clustering algorithm assigns 20 cluster groups, with the intention that each cluster should be equivalent to a different type of activity or terrain. The resultant clustering model can be seen in figure 1. Mathematically, the equivalency of the cluster and class labels is calculated via normalized mutual information, which is currently at 31.1%.

DISCUSSION AND CONCLUSION

99% of the variability in the dataset is explained by the first principal component, which is skewed towards the data from the bilateral amputee, suggesting a separate clustering model should be constructed. Additionally, similarity between labels will be analysed to determine the trade-off in the hierarchical detail of the labels and the cluster model performance. While optimisation of the classifier is still ongoing, the clustering model shows potential to recognize different types of walking terrains for lower limb amputees.

REFERENCES: 1. Jamieson, et al. 2020. Canadian Prosthetics & Orthotics Journal, 3.

ACKNOWLEDGEMENTS: This research was developed for Alexander Jamieson's PhD thesis. Contribution to student fees are provided by PAL Technologies Ltd.

Poster Presentation
Prosthetics: Lower Limb Ankle & Foot

5.35
Mechanical Characterization of Adaptations of Prosthetic Feet in the Frontal Plane

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BACKGROUND
For lower leg amputees everyday tasks like standing and walking on uneven ground are challenging due to the limited adaptability of conventional prosthetic feet. To enhance the frontal plane adaptability (e.g., on cross slopes), prosthetic manufactures have developed prosthetic feet with various design features. However, it was unclear if feet with split-toe design or feet that feature a dedicated ankle joint for inversion/eversion adapt to a higher degree than feet with a continuous carbon forefoot [1].

AIM
The aim was to analyse the adaptations of prosthetic feet to cross slopes and to derive a geometric model that describes these adaptations.

METHOD
Six different energy-storage and return feet with five different designs were considered. A mechanical test device consisted of a self-locking crank for lowering and lifting the prosthetic foot within a solid metal frame was used, figure 1. A L.A.S.A.R-Posture was placed at the bottom of the frame to measure the applied vertical force and to align the feet similarly. Wooden blocks of 0° and 9° inclination were used to simulate level and cross-slope conditions. Loads from 0 to 100kg were applied. A pair of antenna markers were attached on top of each split toe to estimate the twist in the frontal plane with a motion capture system.

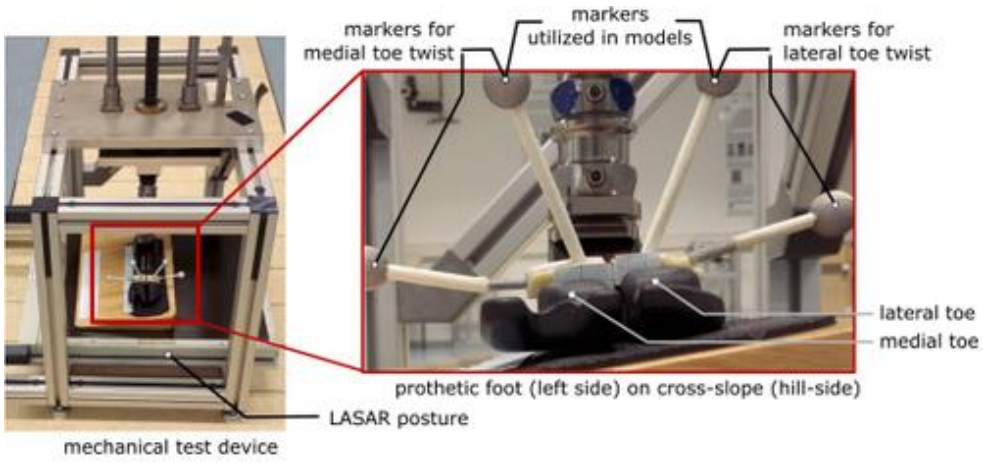

Figure 1. Mechanical test device to estimate frontal plane adaptations shown with a split-toe feet.

RESULTS
Distinct adaptations to cross slopes were found for all investigated feet. The split-toe feet showed a mixture of twist (of toes) and shift (of toes to each other) whereas the ratio depends on the foot type tested. A full adaptation to the cross-slope (i.e. once both toes came in contact with the tilted ground) was found for all split-toe feet but occurred at different loading stages. Here, the foot with the additional ankle joint achieved a full adaptation with the lowest load. The derived model matched the measured data with minor deviations and showed high correlations for all feet. R^2>0.87 was found for the coefficients of the linear equation (twist, shift) describing the overall adaptation.

DISCUSSION AND CONCLUSION
The ability of prosthetic feet to adapt to cross-slopes is design dependent. A split-toe design can adapt better to cross slopes than continuous carbon forefoot feet. An ankle joint allowing for additional inversion/eversion further enhances the adaptability. Furthermore, a theoretical model was successfully derived which describes the feet dependent adaptations. The influence of the foot's adaptability on biomechanical and clinical parameters in standing and walking on uneven ground should be investigated in future and correlated to these findings.

REFERENCES: 1. Ernst et al. 2020 POI 44(4): 225-233

5.36

A Novel Light-Weight Prosthetic Foot Incorporating Woven Intra-Layer Technology for Trans-Tibial and Trans-Femoral Amputees

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BACKGROUND

Amputees experience increased energy cost and gait asymmetry with increased mass of a prosthetic foot[1, 2], partly due to metal connectors. Currently, the carbon fibre prosthetic foot involve metal connectors for linking leaf springs, which may weigh about 30 to 70 grams. Elimination of metallic connectors between leaf-springs can potentially result in significant reducing overall weight, crack propagation, and energy cost[3] thereby improving stability and ambulatory comfort for the amputee.

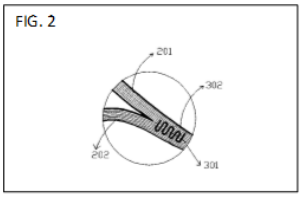
AIM

The objective is to develop a composite lightweight prosthetic foot[4] utilizing a novel technology which eliminates metallic connectors linking leaf-springs, in order to reduce energy cost, improve stability[2,3] and ambulatory comfort for trans-tibial (below knee) and trans-femoral (above-knee) amputees.

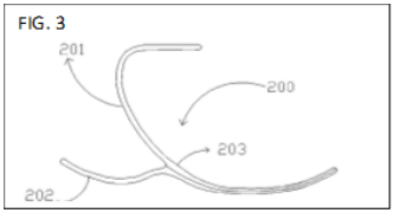
METHOD

The weight of an existing carbon fibre prosthetic foot ranges from about 300 grams to more than 2,000 grams across K1, K2 and K3 categories[2,3]. Referring to prior art, is a representation of existing composite prosthetic foot, with a heavy metallic connector connecting two leaf-springs. The steps for developing an alternative novel light weight foot involved composite technology, experimenting various modalities, incorporation of principles of a prosthetic foot, developing model design, meshing of model and static analysis using FEM/Fatigue analysis and developing prototypes. This developed light weight prosthetic foot incorporating the novel “intralayer system” stitching technology, has undergone reliability testing.

RESULTS



Referring to FIG. 2, is the intra-layer stitching 301 between carbon fibre leaf-springs 201and 202. After the intra-layer stitching, a superficial prepreg layer **302** may be overlaid over the stitch attached layers to avoid the visual exposure of the stitches **301**.The novel light weight prosthetic foot disclosed herein (FIG.3), designed and developed with the “Intralayer System”: The “Intralayer” technology involves three-dimensionally stitching prepreg preforms of the composite leaf springs 201 and 202 at the junction 203, and then further curing the stitch attached prepreg preforms. This three-dimensionally stitching eliminates the possibility of delamination between the two layers of the carbon fibre leaf-springs. Thereby, through this novel technology, this novel foot has eliminated a heavy connector and reduced delamination resulting in a net prosthetic foot weight of about 240 grams, reducing energy cost and improving ambulatory comfort for amputees.



DISCUSSION AND CONCLUSION

The novel prosthetic foot has proven to be lightweight through incorporation of the woven “intralayer system” thereby providing a significant 20% weight reduction (minimum), which reduces energy cost and improves ambulatory comfort. Further, this novel prosthetic foot has demonstrated to be efficacious technically and functionally, as observed from the positive feedback provided by amputees post-fitting. Therefore, these developed prosthetic foot may be fitted for persons with trans-tibial (below knee) and trans-femoral (above-knee) amputations.

REFERENCES: 1. Smith, JD; 2013 J. Appl. Biomech. 2. Mattes, S; 2014 AAOP. 3. Wing DC; 1989 PMR. 4. Houdijk, H; 2018 J. NeuroEng. Rehabilitation.

ACKNOWLEDGEMENTS: I would like to acknowledge BIRAC/CCAMP for their valuable assistance through a grant under the BIG scheme.

5.37

A Novel Light-Weight Prosthetic Foot Incorporating Pyramidal Technology for Trans-Tibial and Trans-Femoral Amputees

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BACKGROUND

Amputees experienced increased energy cost and gait asymmetry with increased mass of a prosthetic foot[1,2], partly due to metallic connectors. Currently, the carbon fibre prosthetic foot involve metallic connectors, linking leaf springs to the pylon. The flat vertical composite section has reduced stiffness, requiring a large form connector to avoid over flexure. The cavity to house this connector weakens its leaf-spring structure in the prior art, hence this requires about 50 to 65 grams composite/connector to minimize high stress and over flexure.

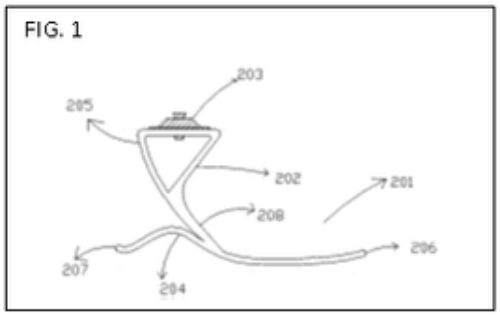
AIM

The objective is to develop a composite lightweight prosthetic foot[4] utilizing a novel technology, which eliminates metallic connectors and minimizes composite material to reduce energy cost, improve stability[2,3], and ambulatory comfort for trans-tibial (below knee) and trans-femoral (above-knee) amputees.

METHOD

The weight of an existing carbon fibre prosthetic foot ranges from about 300 grams to more than 2,000 grams across K1, K2 and K3 categories[2,3]. Referring to prior art, is a representation of existing composite prosthetic foot, exemplarily illustrates an existing prosthetic foot with a heavy metallic connector to connect to the pylon. The steps for developing an alternative novel light weight foot involved composite technology, experimenting various modalities, incorporation of principles of a prosthetic foot, developing model design, meshing of model and static analysis using FEM/Fatigue Analysis and developing prototypes. This developed light weight prosthetic foot incorporating the novel “pyramidal system” technology, has subsequently undergone reliability testing.

RESULTS



The Novel light weight prosthetic foot 201 disclosed herein (FIG.1), designed and developed with the “Pyramidal System”. A hollow light-weight triangular top section 202 is an integral part of a first leaf-spring 208 (originating from 205 and 206) and a second leaf spring 204 (originating from 207 to 206). Fibre continuity is established between the walls of the “Pyramidal System” 202 through a prepeg around the triangular mould. The prosthetic foot 201 disclosed herein comprises a triangular carbon fibre composite section 202 that supports a small form factor metallic pyramidal connector 203. This stiff “Pyramidal System” reduces deflection and does not require a heavy weight metallic connector for added strength. Thereby, this novel foot has eliminated a heavy connector and reduced composite resulting in a net weight of about 230 grams, reducing energy cost and improving ambulatory comfort for amputees.

DISCUSSION AND CONCLUSION

The novel prosthetic foot has proven to be lightweight through incorporation of the “pyramidal system” thereby providing a significant 24% weight reduction (minimum), which reduces energy cost thereby improving ambulatory comfort. Further, this novel prosthetic foot has also demonstrated to be efficacious technically and functionally, as observed from the positive feedback provided by amputees post-fitting. Therefore, the developed prosthetic foot may be fitted for both above-knee (trans-femoral) and below-knee (trans-tibial) amputations.

REFERENCES

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3. Daniel C Wing; 1989 PMR; Energy Storage Prosthetic Foot.
4. Han Houdijk; 2018 J. NeuroEng. Rehabilitation; Energy storing and return prosthetic feet improve step length symmetry.

ACKNOWLEDGEMENTS: I would like to acknowledge BIRAC/CCAMP for their valuable assistance through a grant under the BIG scheme.

5.38
Prosthetic Foot Wear Patterns in Northern Sri Lanka

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[1]London South Bank University, London, United Kingdom. [2]Jaffna Jaipur Centre for Disability Rehabilitation, Jaffna, Sri Lanka

BACKGROUND
Currently, millions are living with lower-limb loss in low- and middle- income countries (LMIC's). The prosthetics used by these individuals often differ from those used in high-income countries in design, method of manufacture, and use. Here, we quantify foot wear patterns in locally manufactured prosthetic feet from Sri Lanka to better understand a) prosthetic use by those with lower-limb loss and b) mechanisms of mechanical failure in locally manufactured prosthetic feet.

AIM
To quantify the wear patterns of prosthetic feet used by individuals with lower limb loss at the Jaffna Jaipur Centre for Disability Rehabilitation (JJCDR) in Jaffna, Sri Lanka.

METHOD
Images were taken of the soles of 16 prosthetic feet replaced by the JJCDR in November 2018. Foot outline was established by digitally drawing around the feet. A grid was placed within the outline, dividing the length of the foot into twenty segments and the width of the foot into ten. Wear was scored from 1 (less wear) to 9 (more wear) for each box individually. The average wear scores for each box were calculated and used to create a composite visualization of foot wear (Figure 1). Mann-Whitney U-tests investigated differences in wear between portions of the foot.

RESULTS
The heaviest worn portions of the prosthetic feet are the heel, end of the keel, and the foot's perimeter (Figure 1). When compared to the rest of the foot, the heel ($U=1228.5$, $p<0.05$), keel ($U=1120$, $p<0.05$), and rest of the foot's perimeter ($U=5003$, $p<0.05$) were significantly more worn. There were significant differences in wear between the heel and keel ($U=89$, $p>0.05$), along with the rest of the foot's perimeter and keel ($U=233.5$, $p>0.05$) and heel ($U=352$, $p>0.05$).

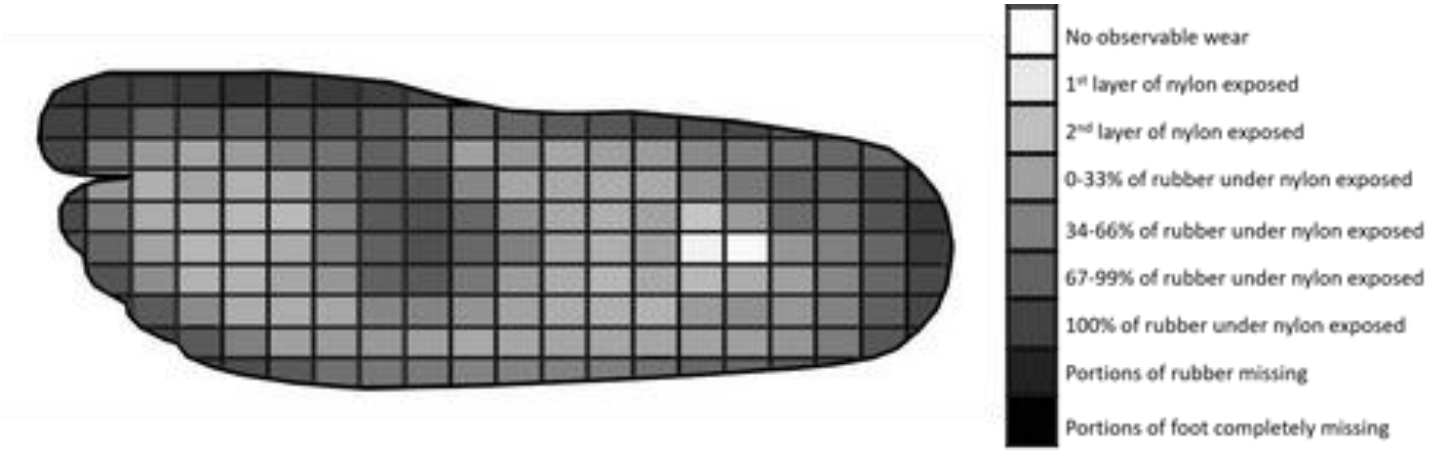

Figure 1. Wear patterns of the prosthetic feet

DISCUSSION AND CONCLUSION
Feet showed highest level of wear under the keel and around the perimeter where forces would be highest due to locomotor forces. Alterations of this methods are needed for applications to feet that do not have nylon on the bottom (e.g., vulcanised rubber). Unknown age and use of prosthetic feet likely impact our results. To the authors' knowledge, this is the first study to characterise prosthetic foot wear.

ACKNOWLEDGEMENTS: JJCDR for working with us and providing the prosthetic feet and the NIHR PrOTeCT grant (16/137/45) for funding this research.

5.39

Comparison between a Robotic Prosthetic Foot Emulator and Corresponding Commercial Prosthetic Forefoot Angular Stiffness Properties

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BACKGROUND

The prosthetic foot emulator (PFE) is a robotic foot-ankle that can be attached to a prosthetic socket to mimic commercial prosthetic forefeet [1]. Using the PFE, patients with lower limb amputation (LLA) could quickly experience walking with different types of feet. To achieve emulation, commercial feet are mechanically tested, and the data (i.e., ankle torque vs angle) are then used to recreate the properties of corresponding feet. However, it is currently unknown how accurately these procedures emulate forefoot properties.

AIM

Therefore, the purpose of this study was to assess the agreement between the angular stiffness properties of emulated feet and the corresponding commercial prosthetic forefeet, in a user-independent fashion.

METHOD

Mechanical testing was used to collect angular stiffness data for a range of prosthetic feet in two sizes (26 and 27cm) and two body weights (175 and 200lbs). The commercial feet were Walk-tek, Seattle Lightfoot2, Variflex, Rush HiPro, and All-Pro. The forefeet were isolated at +20° and loaded for six cycles using a R2000 robot, while a load cell collected forces and moments and a motion capture system collected kinematics. Centre of pressure relative to the PFE axis defined ankle angle. Data for each foot was fit with a Bezier curve for input to the PFE (Figure 1). These procedures were then repeated with the PFE configured as each foot.

RESULTS

Differences in ankle torque were calculated for at every 0.01° ankle angle between commercial and emulated feet. Linear mixed effects regression was used to assess correlation between emulated and commercial foot properties and to quantify effect of factors on the correlation, such as ankle angle position, foot type, and foot size. Finally, Bland-Altman limits of agreement analysis was used to assess agreement between emulated and commercial foot measurements. The mean difference in angular stiffness between emulated and commercial feet ranged from -1.3% to +2.5% (-0.32 ± 1.35Nm/deg) across feet. Emulated foot properties were significantly correlated with commercial foot properties and ankle angle ($p<.001$), and there was no effect of foot type or size. Limits of Agreement between the emulator and the corresponding commercial feet were -3.12 to +4.67Nm across ankle angle positions, with a mean bias of 0.77Nm between conditions.

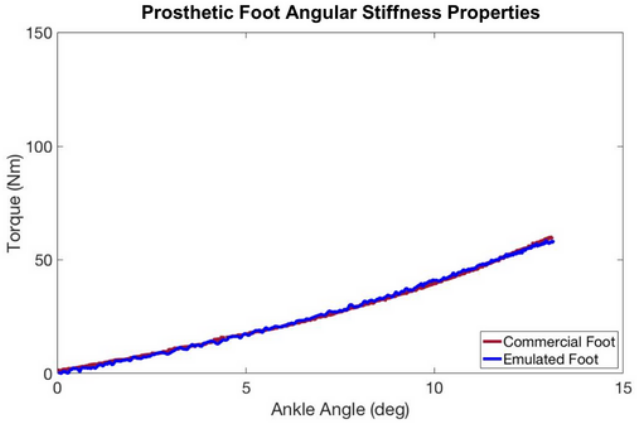

Figure 1. Example angular stiffness (i.e., ankle torque vs. angle) of commercial prosthetic foot and corresponding emulated foot.

DISCUSSION AND CONCLUSION

Mean differences between emulated feet and the respective commercial feet were less than the minimal detectable difference in angular stiffness previously estimated for people with LLA (i.e. 7.7%) [2]. These results demonstrate the high agreement between emulated and commercial forefoot angular stiffness using the PFE. Future study is needed to compare gait biomechanics between conditions. Optimizing the angular stiffness of emulated forefeet will improve the utility of the PFE for test-driving feet to augment prosthetic foot prescription.

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ACKNOWLEDGEMENTS: This work was supported by the U.S. Department of Defense through the OPORP Award No. W81XWH-16-1-0569 (PI: Morgenroth).

5.40

Redesign and Construction of Low-Cost Bionic Ankle-Foot Prosthesis for Transtibial Amputee to Facilitate Normal Gait with Arduino Nano

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Instituto Politécnico Nacional, Zacatecas, Mexico

BACKGROUND

The prominence of vascular disease in Mexico makes searching for solutions for amputees' mobility an opportunity area [1]. Depending on the amputee's condition, a prosthesis can be used [2]. The production of national devices is lower than needed, and some foreign prostheses are not affordable for the average Mexican citizen. This project emerges as a continuation of a previous work, which developed a bionic ankle-foot prosthesis [3] and now following the natural gait cycle movements [4].

AIM

Design, and implementation of a bionic ankle-foot prosthesis, using a worm-wheel mechanism to emulate natural gait applying PD control to a DC motor with an Arduino Nano and an encoder.

METHOD

The design is symmetric and anthropomorphic considering plantar pressure. Space is designated for internal components as a spring, a motor, and a transmission mechanism. Also, aluminium 1060 H16 and onyx filament for 3D impression are proposed to use. Using a DC motor that rotates to both sides, a series of pre-set positions are generated, emulating the cycle gait. With the implementation of PD control and an encoder, the position is successfully achieved. The electronic system is conformed of a PCB circuit that includes an energy source, DC motor, Arduino Nano, a rotative encoder, a motor driver carrier, switches, and an indicator LED.

a) b) c)

Figure 1. Testing comparison, a) Static b) Suspended c) Movement. To test it with movement, the prosthesis was added to a structure attached to a person's leg while walking on a treadmill at 1.44 mph.

RESULTS

The design was simulated on CAE software applying static and fatigue analysis. According to simulations, the proposed design is acceptable for a user of 97.6 kg with a 1.53 security factor. Regarding the control part, a closed-loop MatLab Simulink simulation was developed for the motor behaviour. A prototype of PLA filament and Aluminium was constructed as a first step to detect opportunity areas in the design. The physical position of the encoder limited the space of movement. The prototype's functionality was proved statically (to inspect the correct four positions gait cycle and time), suspended (carrying its own weight), and with real movement.

DISCUSSION AND CONCLUSION

This prototype is the start of an investigation and collaboration with a Mexican prosthetic company about lower limb prosthesis. The project encourages the development of technology application in medicine which improves people's mobility and life quality. It also represents several opportunities for improving issues with regard to the reduction of space and protection of different components in the prototype. The objective of redesigning and constructing the prototype conserving components was accomplished successfully.

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ACKNOWLEDGEMENTS: First author thanks PROBIONICS for the opportunity to work with them, their confidence, and their support throughout the project.

5.41

Ascending Ramps with an Active Prosthetic Foot: Metabolic and Biomechanical Effects

Malte Bellmann[1], Siegmar Blumentritt[2], Felix Oswald[2], Eva Pröbsting[1], Thomas Schmalz[1]

[1]Ottobock SE & Co. KGaA, Göttingen, Germany. [2]Private University of Applied Sciences, Göttingen, Germany

BACKGROUND

Active prosthetic feet are designed to generate a push-off during late stance phase. Scientific results describing the biomechanical and metabolic effects are contradictory: Some studies report reduced energy consumption [1,2] and sound side knee load [3-5], other studies show no significant effect [6,7]. There is no study analysing the effect of active push-off in an isolated way by systematically excluding the influence of other constructional features (e.g. mass).

AIM

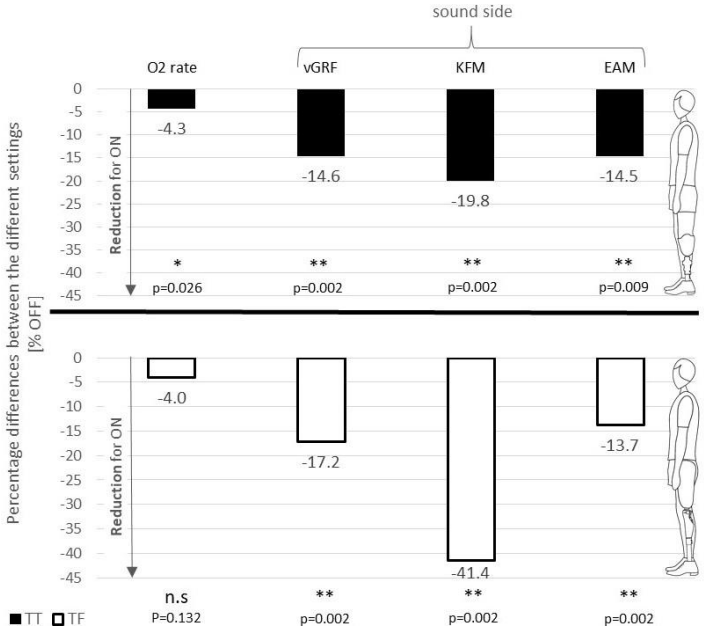
Analysing the effects of an active prosthetic foot on the metabolic energy consumption and gait biomechanics of a transtibial (TT) and a transfemoral (TF) amputated person while ascending ramps.

METHOD

This case study design included one TT and TF each. Ascending a 5° ramp with an active foot optimally adjusted with (ON) and without (OFF) active push-off was analysed. Four measurement sessions with three examinations each were completed with both subjects within 2 weeks. Each examination incorporated spiroergometry measurements (treadmill design) and motion analyses using an optoelectronic system and one force plate (gait lab ramp design). The order of the foot setting (ON or OFF) was randomized for the respective examinations within one session. There were 6 possible orders of foot settings: ON/OFF/ON, OFF/ON/OFF, ON/ON/OFF, OFF/OFF/ON, OFF/ON/ON, ON/OFF/OFF.

RESULTS

The walking velocity shows no differences between the foot settings (0.55±0.02m/s (TT), 0.63±0.02m/s (TF)). For both amputees, the difference of the stance duration between the prosthesis and the sound side is decreased with ON (5.8±0.6% vs. 3.4±0.5% (TT), 4.9±0.5% vs. 2.6±0.6% (TF)), resulting in a higher symmetry of this parameter. The O_2 rate was significantly reduced by 4.3% (p=0.026) for the TT with ON, no significant differences were measured for TF (Figure 1). The sound side peak values for the external knee adduction moment (EAM), the knee flexion moment (KFM) and the vertical ground reaction forces (first peak, vGRF) were highly significantly ($p<0.01$) reduced for both amputees with ON (Figure 1).



DISCUSSION AND CONCLUSION

For both amputees the active push-off resulted in an increased symmetry of stance phase duration and a reduction of the sound side knee load. The slight metabolic effects, not in accordance with other studies [1,2], indicate that metabolism of lower limb amputees reflects a framework of different factors. Summarizing metabolic and biomechanical results, an active push-off facilitates ascending ramps for lower limb amputees. Nevertheless, further studies are required to assess the overall potential clinical benefit of active prosthetic feet.

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5.42

An Approach for a Dynamic Prosthetic Treatment of Patients with Partial Foot Amputations

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BACKGROUND

After a partial foot amputation, a prosthesis serves as cosmetic and functional replacement for the missing anatomic structures. The support provided by a prosthesis mostly depends on the length of the residual limb and the according muscular restrictions. The CPO has to choose between sub-ankle prostheses providing insufficient functional compensation and above-ankle prostheses blocking the range of motion in the anatomic ankle joint and leading to contractures. With both kinds of treatment, a dynamic support is not possible.

AIM

Our aim was to combine the properties of a dynamic orthotic ankle joint with a partial foot prosthesis. Therefore, a critical consideration of the dynamic properties in current prostheses was performed.

METHOD

The group of sub-ankle prostheses includes 1) toe fillers or forefoot replacements (foam), 2) toe prostheses with midfoot socket (mostly silicone) and 3) sub-ankle foot prostheses. The sub-ankle foot prostheses are mainly slipper prostheses with flexible socket and forefoot replacement (foam or silicone). The group of above-ankle prostheses includes 4) combinations of sub-ankle foot prostheses with ankle-foot orthoses (AFO) and 5) clamshell prostheses. The dynamic properties of these prosthesis types were compared to a new type of partial foot prosthesis with dynamic orthotic ankle joint and pre-compressed spring units (6) regarding dorsiflexion stop, spring force, alignment, pivot point, plantar flexion, heel rocker, range of motion and appearance of shear forces.

RESULTS

Prosthesis types 1)–3) are mainly for cosmetic use and provide almost no functional compensation. Since the ankle is left free, the evaluation criteria of a dynamic treatment are not applicable for this assessment. The shear forces depend on the secure fit of the residual limb. Types 4) and 5) are used mostly for high amputation levels and provide ankle stability by blocking the range of motion of the ankle. The missing muscular functions must be compensated with the high and variable spring force of pre-compressed spring units. Since a defined pivot point and the range of motion are missing, the forefoot lever cannot be activated to provide stability when standing and walking (see table 1).

Prosthesis Type	Dynamic Properties							
	Dorsiflexion Stop	Spring Force	Alignment	Pivot Point	Plantar Flexion	Heel Rocker	Range of Motion	Shear Forces
1) toe filler or forefoot replacement	*not applicable (n/a)*	*n/a*	*n/a*	*physiological*	*n/a*	*n/a*	*n/a*	*high*
2) toe prosthesis w/ midfoot socket	*n/a*	*n/a*	*n/a*	*physiological*	*n/a*	*n/a*	*n/a*	*medium*
3) sub-ankle foot prosthesis	*n/a*	*n/a*	*n/a*	*physiological*	*n/a*	*n/a*	*n/a*	*medium*
4) sub-ankle foot prosthesis w/ AFO	*static*	*not variable*	*not adjustable*	*not defined*	*not possible*	*not possible*	*not adjustable*	*high*
5) clamshell prosthesis	*static*	*not variable*	*not adjustable*	*not defined*	*not possible*	*not possible*	*not adjustable*	*medium*
6) partial foot prosthesis w/ dynamic orthotic ankle joint	*dynamic*	*variable*	*adjustable*	*defined*	*passive*	*possible*	*adjustable*	*low*

Table 1

DISCUSSION AND CONCLUSION

The evaluation criteria we used have already been established for the orthotic treatment of CP patients and proven to be valid. This critical consideration shows that a dynamic approach is still missing within the available selection of prostheses for patients with partial foot amputations. Especially patients with a high amputation level need stability as well as a range of motion. The use of a dynamic orthotic joint in a partial foot prosthesis can be a step towards this approach.

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5.43

An Investigation into the Influence of the Nike Sole on Stiffness and Energy Efficiency of Ossur Flex-Run Running-Specific Prosthesis

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BACKGROUND

Running-specific prostheses (RSP) are designed to act as springs, storing and returning energy as efficiently as possible. They are used without cosmetic covers but might require different ground interfaces. The Nike Sole (Beaverton, OR) is designed to attach to the Flex-Run RSP (Ossur, Reykjavik, Iceland) [1]. It includes an outsole, midsole, a urethane interface with the RSP, and nylon tabs for attachment [2]. No study has measured the effects of the Nike Sole on the material properties of the RSP.

AIM

The purpose of this study was to assess the stiffness and hysteresis properties of the Flex-Run with and without the Nike Sole.

METHOD

A Flex-Run foot kit with Nike Sole, Category 4HI, was tested in compression on a 312-47 Series Universal Testing Machine (Test Resources, Shakopee, MN). The foot was placed in maximum plantarflexion allowed by the pyramid adapter and a rolling surface minimized shear resistance. Ramp loading and unloading tests at 50 N/s to 200N were conducted with (S) and without (NS) the Sole attached, with data were recorded at 125 Hz. Stiffness was determined by linear regression. Hysteresis between 10 and 200 N was calculated by numerical integration. Multiple tests showed nearly identical results, so a single representative test from each case was analysed.

RESULTS

Results revealed reasonably linear loading with minimal hysteresis (Fig. 1). In loading up to 100 N, stiffnesses were almost identical (170.3 N/cm, R2=0.999 for S, 162.29 N/cm, R2=0.999 for NS). At approximately 135 N, the stiffness increased for only the S condition to 264.53 N/cm.
The hysteresis for the S condition was 3.9 Ncm while the hysteresis for the NS condition was 1.76 Ncm.

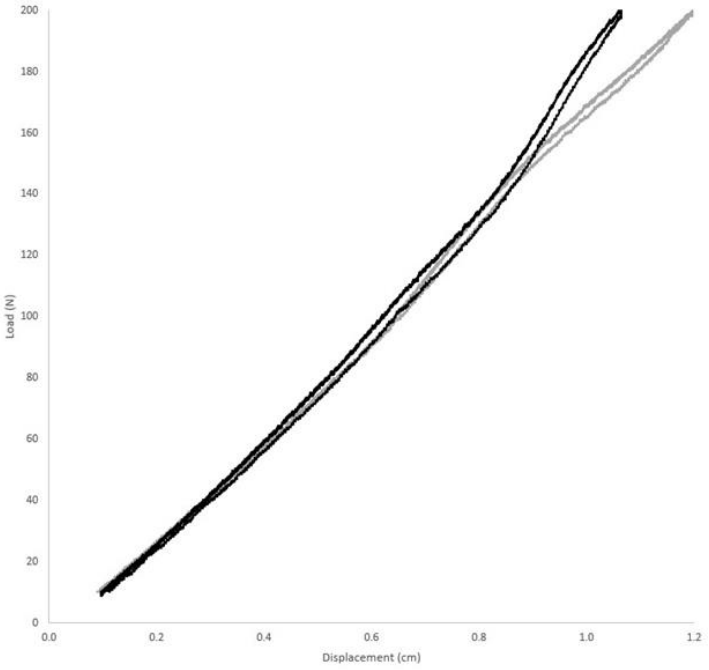

Figure 1: Load-deformation results for S (darker line) and NS (lighter line)

DISCUSSION AND CONCLUSION

The properties of RSPs are carefully chosen to optimize performance but are often determined from the base foot without regard to ground interface. These results showed that the Sole stiffens the Flex-Run at higher loads. It also increases energy loss, but hysteresis is both conditions was very small, and the difference due to the Sole is likely not clinically significant. Given the inflection point in stiffness with the Sole, the condition should be tested to higher loads in future study.

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ACKNOWLEDGEMENTS: Thanks to Lexie Fuson for setup and data collection and Kevin McFall for coupler fabrication.

Poster Presentation
Prosthetics: Upper Limb

5.44
Opinion of Myoelectric Upper Limb Prosthesis Users in Slovenia on Lack of Sensation

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BACKGROUND
In spite of huge development in the field of upper limb prosthetics in the last two decades, a prosthesis still does not restore sensation. A myoelectric prosthesis user has no information about gripping, the grip force, sliding of an object, temperature, shape, material and all other sensations that we can get from our hands.

AIM
We wanted to find out the opinion of myoelectric upper limb prosthesis users about the importance of sensation with prostheses, how important are for them activities for which sensation is important and about advantages and disadvantages of their myoelectric prosthesis.

METHOD
We prepared especially for this study a survey with 14 questions and sent it together with information about the project, informed consent and post envelope with stamp and our address on it to all aged at least 18 years and use a myoelectric prosthesis or wore it in the last ten years, together to 34 people.

RESULTS
We got 11 answers, from seven men, 18 to 83 years old, all after trans-radial amputation, 3 after amputation of both upper limbs. For seven it is extremely important that they can feel with the prosthetic hand and also manipulating with fragile objects, followed by ability to clean the glove. Ten wanted to feel touch with an object, nine sliding of an object and grip force, seven to feel also temperature of the object. Six preferred to get information via vibration, two with vision, one by vision and sound and one by vision and vibration. The main advantage of their myoelectric prosthesis is its function (allows them being independent, help at different daily activities). The main disadvantage is cosmetic glove which is quickly dirty and is very difficult to clean.

DISCUSSION AND CONCLUSION
In spite that all who answered our survey were very experienced myoelectric prosthesis users, they still reported that sensation with prosthesis is for them extremely important. Most wanted to get more than just one sensory information. The second most important feature was ability to clean the glove. It seems that developing a system restoring at least some sensation will be helpful for users of myoelectric upper limb prosthesis as well as gloves that will be easy to clean.

5.45
Rehabilitation of Auricular Defect: First Experience in Sub-Saharan African Country Ghana

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BACKGROUND
Amputation of body limb or partial amputation of the body part leaves subjects to several forms of disability associated with stigmatization and psychological aspect of the patient. The rehabilitation of persons with facial amputation in low resource countries using advanced prosthesis technique remains very challenging for professionals due to training facilities and lack of appropriate materials.

AIM
This case report describes one of the first attempts of the rehabilitation of a patient with auricular defect due to trauma in Ghana, West Africa.

METHOD
A male patient in his fifties presented at our prosthetic office with partial deficiency of the right ear due to trauma. The subject had requested auricular prosthesis to improve the quality of life. The manufacturing of the prosthesis consisted of the following steps: the impression taking, the wax pattern and the laboratory procedures as described in former report [1]. The impressions were taken with hydrophilic vinyl polysiloxane impression material on the normal and on the defect ears of the subject. For about 10 minutes, the negative impressions were taken off after setting. The negatives impressions were used to make three part-moulds for silicone solution injection.

RESULTS
Through the technique described above, real looking auricular prosthesis as patient skin colour was manufactured and fitted with adhesive on the patient (Figure 1, C). The patient was satisfied with the fitting of the prosthesis.

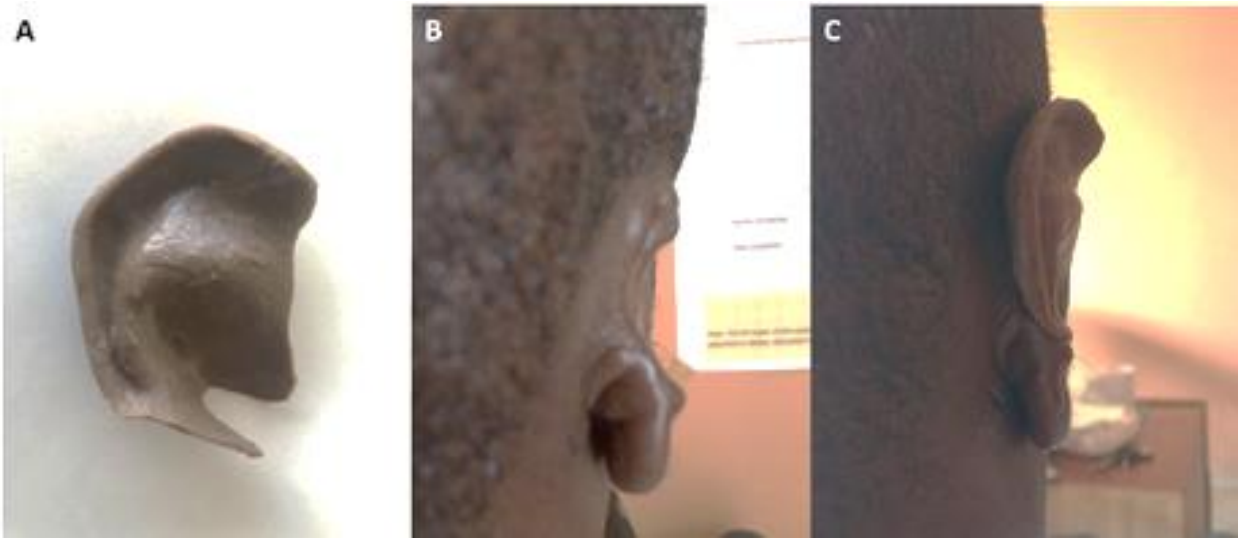

Figure 1: A) Aspect of the manufactured prosthesis B) Before the prosthesis C) After wearing the prosthesis during fitting

DISCUSSION AND CONCLUSION
The rehabilitation of auricular prosthesis using real silicone was one of the first attempts to fit an ear partial amputation subject in Ghana, West Africa. In case of partial facial amputations, though the functional aspect might have less consideration, the aesthetic aspect is highly recommended. For better rehabilitative service and quality of life of people living with facial defects, awareness and availability of silicone technology need to be considered.

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5.46

Development of a Motorized Prosthetic Hand for Infants with Phocomelia

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BACKGROUND

There is a congenital disorder called phocomelia. Phocomelia is a condition in which the residual finger looks like it is growing out of the shoulder. This residual finger is unable to exert strong force. Yamaguchi et al. developed a prosthetic hand for this condition, but it is thought to be difficult to adapt to infants because the prosthetic hand is heavy [1].

AIM

This study will develop a motorized prosthetic hand that can be operated by infants with phocomelia, a condition that prevents them from exerting strong force.

METHOD

The developed Powered Prosthetic Hand consists of One DOF mechanical hand actuated by DC servo motor and controller, and sensor which detects an intention of motion by using bending sensor or approximately sensor. The user can adjust the amount of manipulation of the prosthetic hand by using these sensors. We tested whether an infant can operate a prosthetic hand equipped with these sensors. The subjects were one infant under the age of two.

RESULTS

The subject was not able to operate the prosthetic hand equipped with the bending sensor. However, the subject was able to operate the prosthetic hand equipped with a proximity sensor after a short period of training. They were also able to hold objects such as blocks by their own will. The prosthetic hand equipped with a proximity sensor had a wide space in the socket, so even young children were able to wear it without discomfort. Furthermore the subject has started to communication by hand shaking with his mother and father by using prosthetic hand.

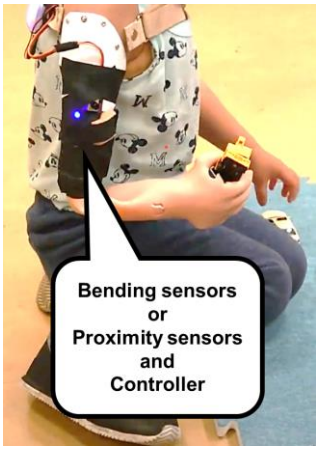

Figure 1. A subject applying prosthetic hand

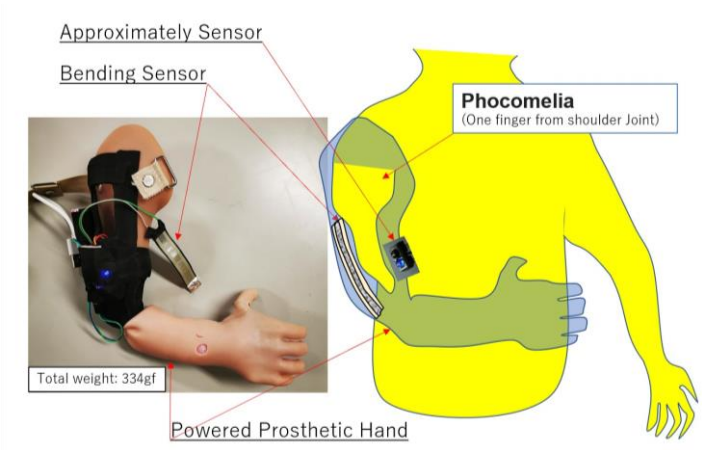

Figure 2. Powered Prosthetic Hand system for Children

DISCUSSION AND CONCLUSION

The bending sensor was able to detect finger motion theoretically, however this sensor might be too difficult to find out the relationship with sensor function and the reaction of powered prosthetic hand or how to use this system for this subject. Therefore, it is considered necessary to apply a prosthetic hand that is clear and easy to operate to infants.

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ACKNOWLEDGEMENTS: This research is partially supported by JSPS KAKENHI [Grant Number JP18H03761].

5.47

Influences Affecting Acceptance and Rejection of Prosthetic Usage in the Upper Limb Congenital Below Elbow Deficiency Population

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BACKGROUND
The congenital upper limb deficient population represents the most impressionable patient group as they are affected from birth; factors and influences during their early years could have a significant impact on lifelong prosthesis usage.

AIM
This pilot study examined the role of personal experience growing up and its potential effects on prosthesis usage using semi-structured interviews with upper limb congenital below elbow deficiency participants.

METHOD
Five members of the University of Salford's professional patient database with upper limb congenital below elbow deficiency were included in this study. Qualitative data, in the form of short face-to-face interview, was collected through a series of open ended questions pertaining to influences in their childhood; specifically relating to their parents, prosthetist, and wider social circle.

RESULTS
For the subjects of this pilot their parents played a significant role in their prosthetic rehabilitation. All families in question had to fight to get a prosthesis so that their child could fit in a little easier and to ensure that the child did not feel they were different or in any way disabled. It was clear that the prosthetist was held in high esteem; however, they were not considered a significant influence in the decision to wear the prosthesis. The wider social circle continues to have an impact on prosthesis wear for subjects interviewed. All touched on being very conscious of the need to blend in when in public; this is openly accepted by them taking off their prosthesis when they relax. This desire to fit in strongly influenced the acceptance of a prosthesis for all interviewed.

DISCUSSION AND CONCLUSION
All participants recognised the importance of support and its influence on their prosthesis usage during childhood, but more work is needed to establish the effects of modern-day influences on the acceptance and rejection in the Congenital Below Elbow Deficiency Population as the results gathered have inadvertently highlighted the influence of technology as subjects interviewed grew up before the dawn of the information age, before the internet unlocked the vast array of options available.

5.48

Development of the Assessment of Capacity for Myoelectric Control Version 4 for use in Patients with Multi-Grip Prosthetic Hands

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BACKGROUND
Myoelectric prosthesis fitting require training for daily use. In order to determine the need for training, patients' skill should be evaluated. The Assessment of Capacity for Myoelectric Control (ACMC) is a 22 item, 4-category rating scale, measurement method (1, 2). Over the years, users of the ACMC have suggested addition of an item that covers pre-positioning of the hand. Furthermore, there is a need to measure the ability to control functions of multi-grip prosthetic hands.

AIM
The aim was to further develop and validate the Assessment of Capacity for Myoelectric Control for use in patients with upper limb loss and multiple prosthetic functions.

METHOD
Four international occupational therapists, experienced in ACMC and fitting of multi-grip prosthetic hands, participated in the first step of the process.

Three meetings were held where three potential items were identified and item definitions and scoring criteria were defined. The goal was to identify items that may capture differences in patients' skill in operating a multi-grip prosthetic hand. Individual scoring of 3 patient videos by each member of the expert group was completed. The results showed a uniform interpretation of the item definition and scoring criteria.

Pilot-test of item definitions and scoring criteria were made by participants at ACMC training courses in Sweden and Canada.

RESULTS
Three new items were developed from the multiple expert meetings: 1) Positioning the hand appropriately for gripping; 2) Ability to switch grips; and 3) Choosing the appropriate grips for function. Definitions and scoring criteria of the original 22 ACMC items were modified for clarity. The definitions of the new items followed the original four-graded (0-3) ACMC scoring criteria.

The pilot-testing of item definitions and scoring criteria was completed by participants at ACMC training courses in Örebro, Sweden. The additional items proved to be comprehensive and understood for the new raters and no changes were needed.

DISCUSSION AND CONCLUSION
The new items will complement the original ACMC (1) to better assess the functional skill level of those who use more sophisticated prosthetic hands. The original ACMC has been well validated (1, 2) and the next step will be a full international validation study with the new items included.

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ACKNOWLEDGEMENTS: We would like to thank the participants that took the ACMC-courses, reviewed the new items and definitions and provided feedback.

5.49

Exploring the Relationship between Residual Limb Length, Strength and Range of Motion Impairments of Veterans with Upper Limb Amputation

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BACKGROUND
Variability exists in residual limb length (RLL), strength, and passive range of motion (PROM) impairments in persons with upper limb amputation (ULA). The relationship of RLL, PROM restrictions, and strength impairments to activity performance, disability, health related quality of life (HRQoL) and prosthesis satisfaction have not been previously explored.

AIM
The study aimed to provide detailed description of RLL, PROM impairment, and strength deficits in Veterans with major ULA, and to quantify the association between these factors and outcomes.

METHOD
Data was collected during in-person visits in a multi-site, cross-sectional, observation study. Demographics, prosthesis characteristics, RLL, and prevalence of PROM and strength deficits were described. Linear regressions examined associations between impairments and activity performance, HRQoL, disability and prosthesis satisfaction.

RESULTS
The sample included 107 participants, 70% below elbow (BE) and 30%above elbow (AE), 97% male, 88% Veteran, mean age of 57.1 (SD 16.1) years, 58.9% body powered prosthesis users. Prevalence of short below elbow (BE) and above elbow (AE) residua was 25.7%, and 12.5% respectively. In regressions, Activities Measure for ULA (AM-ULA) scores were worse for those with shoulder extension? PROM restrictions (B=-5.0, p=0.03) and better for those with flexion restrictions (B=3.3, p=0.04) compared to normal PROM. Prosthetic satisfaction was lower for those with restriction of elbow PROM. No impairment was a significant predictor of Veterans Rand (VR-12) PCS or QuickDASH, scores.

DISCUSSION AND CONCLUSION
smaller proportion of participants with AE as compared to BE amputation had either short/very short residua, consistent with clinical observations that it is more difficult to achieve adequate socket suspension for persons with shorter AE amputation than it is for those with shorter BE amputations. Few significant associations were found between impairment variables and outcomes. There are limits to the generalizability of our findings to non-Veterans, women and persons who do not use a prosthesis.

ACKNOWLEDGEMENTS: This research was funded through the Orthotics and Prosthetics Outcomes Research Program Prosthetics Outcomes Research Award under Award No. W81XWH-16-0794 and by A9264-S Department of Veterans Affairs Rehabilitation Research and Development Service.

Poster Presentation
Device Fabrication and Design

5.50
Preliminary Study: Local Prototype of Orthotic Ankle Joint

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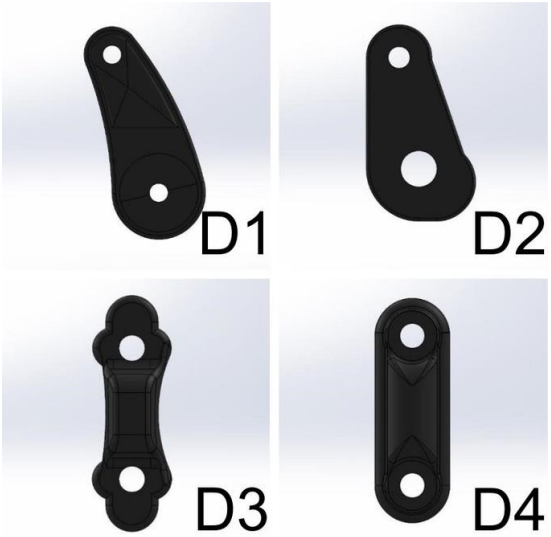
BACKGROUND
Jointed Ankle Foot Orthotics (AFO) is commonly used to improve walking pattern due to drop foot which commonly caused by neuromuscular cases. Fabrication of jointed AFO needs orthotic ankle joint. In Indonesia, this component can be categorized as an expensive one due to being imported. Studies about low-cost orthotics/prosthetics in worldwide were established with good outcome. Therefore, this research is a preliminary study of developing local prototype of orthotic ankle joint in Indonesia.

AIM
This innovative research was a preliminary study to develop the prototype local orthotic ankle joint with a computerized aid designing and engineering testing process.

METHOD
Developing prototype orthotic ankle joint process were divided into (1) conducting preliminary survey to identify which orthotic ankle joint type would be used as gold standard (DG) in this study (2) literature study of DG as well shape and materials for the prototype (3) 3D modelling of orthotic ankle joint by using Autodesk INVENTOR (4) engineering testing; finite element analysis (FEA) by means of SOLIDWORKS was utilized to identify which design and material have the best outcome as the prototype by comparing its mechanical properties (i.e. yield strength, tensile stress, modulus elasticity, stress, etc.) to DG's mechanical properties of shape and material.

RESULTS
The survey showed that 75% orthotists in Indonesia use flexible type of orthotic ankle joint to fabricate jointed AFO. Literature studies revealed that DG made from polyurethane to provide flexibility and a load bearing element made from Teflon to provide a longitudinal strength and stiffness to the joint. Four designs of shape (D1, D2, D3 and D4) were obtained and five possible materials namely high-density polyethylene (HDPE), low-density polyethylene (LDPE), nylon, polypropylene homo-polymer (PPH), and polypropylene copolymer (PPC) were included in this study. Materials wise, FEA results revealed that nylon has similar quality as polyurethane with magnitude of $2.62x10^9$ N/m^2, $10.3x10^7$ N/m^2 and $9x10^7$ N/m^2 for elastic modulus, yield strength and tensile strength consecutively. In terms of shape, D3 (i.e. clover) has the highest maximum value of stress, strain and displacement ($3,65x10^7$ N/m^2, $1,12x10^2$ N/m^2 and $1,62x10^1$ N/m^2).



DISCUSSION AND CONCLUSION
Nylon was proved to have the best outcome of strength and stiffness which are close to DG's material (i.e. polyurethane). For shape wise, D3 (i.e., clover) has the closest magnitude of strength parameters to the DG. Therefore, one can conclude that local prototype of orthotic ankle joint can be made out of nylon with clover shape. In the future study, this prototype could be manufactured and followed by the clinical trial.

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5.51

Designing a New Stance Control Orthosis Using a Self-Locking Mechanism Using the User's Own Weight

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BACKGROUND

A stance-control knee-ankle-foot orthoses (SCKAFOs) is a type of knee-ankle-foot orthosis (KAFO) that allows wearers to flex their knee when swinging the leg forward while preventing knee flexion while weight-bearing [1]. As commercial SCKAFOs satisfy at least one requirement, most of them are bulky, noisy, heavy and expensive. This new orthosis proposal is characterized by allowing the knee to be locked at any flexion/extension angle using the user's own weight, even when it's fully extended.

AIM

To design and build a new approach for a SCKAFO type knee orthosis. It requires no external control system. The control is carried out in response to the user's own movements and weight.

METHOD

A prototype was modelled using Autodesk Inventor. This prototype consists of a compressing spring, a stirrup - with an opening in the body to support the spring, a two - pieces case, a rubber covering attach to the lower side of the stirrup and a bar with a rotation axis. In the stance phase, with the weight of the body, the stirrup moves downwards, compressing the spring. The rubber covering contacts the surface of the lower bar, locking the movement by friction. As the weight of the body over the stirrup decreases during the swing phase, the spring returns the stirrup to its original position which unlocks the joint.

RESULTS

A simulation was run using a 3D model generated in Autodesk Inventor. In extended position, a force of 882 N (considering a maximum mass of 90 Kg) was applied in the x axis to the lower bar, against the hyper extension limit in the case, resulting in a safety factor of 2.91. As shown in figure 1.A, the concentration of stresses occurred in the intersection between the bar and its rotation axis.

In flexed position, the same force of 882 N was applied to the lower bar but in the opposite direction to observe the displacement suffered by the bar when the stirrup is down and activated. The maximum displacement (shown in 1.B) in 'x' was of 0.002007 in, showing that the SCO system would lock the knee in extension when the stirrup activates.

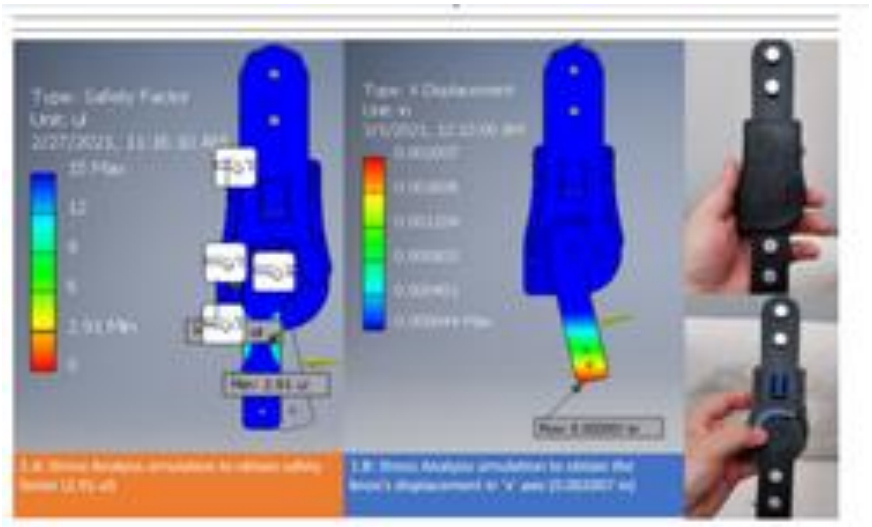

Figure 1: Results obtained after the stress analysis simulations run to the 3D model of the new proposed SCO design.

DISCUSSION AND CONCLUSION

The simulation run in extended/flexed positions confirms that the SCO will, theoretically, lock the knee when the user's weight is applied at different angles. It is also shown that the hyperextension bump can withstand the applied force of the knee avoiding hyperextension. Nevertheless, as the simulations show that the model theoretically aligns with the SCO definition, more tests are needed with the proposed materials to demonstrate that it would work, in practice, as it does in the theory.

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5.52

Design, Manufacture and Pilot Test of a Dynamic Response Prosthetic Foot made of Natural Fibres

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BACKGROUND

In Colombia, get prosthetic treatment can be extended from 5 months to 2 years[1]. The low-income population is the most affected, since they spend more time without prostheses and cannot actively contribute to the economy of their family[2]. This project seeks to venture into the manufacture of a prosthetic foot with a dynamic response based on natural fibres, with the aim of making this prosthetic element more accessible to the Colombian population and can re-enter their daily lives.

AIM

Design and manufacture a prosthetic foot with a dynamic response based on natural fibres. Test the mechanical performance of the prosthetic foot according to the "AOPA's Foot Project Report[3]", measuring displacement and energy return in the keel and heel.

METHOD

"Design Thinking" methodology centred on the user was implemented. As a first step, information was collected from users, establishing functional, operational and aesthetic requirements; from these, the sketching was carried out taking into account the initially defined parameters and the ergonomics of the human foot. At the same time, mechanical tests were carried out on the natural fibre composite material. The final design was simulated in 3D by testing with finite elements in order to optimize the design. Subsequently, a method of manufacturing the prosthetic foot was innovated, manufacturing two prototypes. Finally, to validate the prototypes, mechanical tests were carried out on the keel and heel following the AOPA[2] guidelines.

RESULTS

Two prosthetic foot prototypes were manufactured, the first consisting of three pieces (**C3**), the second consisting of two pieces (**C2**). The results of the AOPA tests were, in **C3**, ***heel: displacement of 25mm at 1200N***, ***keel: displacement of 25mm at 500N***; C2 testing was only possible on the ***heel: 17mm offset at 1150N***. In both models it was not possible to evaluate the energy return. The results were compared with two prototypes that were subjected to the same tests: DynaJ[4] and Vari-flex[5]. The C3 in the keel, absorbs 67% more than the DynaJ. Regarding the heel, the C3 model adsorbs 58% more than the Vari-flex.

Figure 1. Manufactured prototypes. Left prototype **C3**. Right prototype **C2.**

Test / Prosthetic foot	Keel	Heel
C2	0	837
C3	3842	1756
DynaJ	1266	2844
(Vari-flex)	2760	728

Table 1. Value of the area under the curve in the keel and heel tests of the prosthetic feet at 400N. Energy absorbed by prosthetic feet.

DISCUSSION AND CONCLUSION

The mechanical performance results were positive and show great energy absorption, fulfilling the required displacement in both the keel and the heel, however, the energy return could not be evaluated, it was not possible to classify them as dynamic response feet. To achieve this, a geometric optimization is required, in the parts where there was fracture. This project lays the functional and formal bases for the manufacture of dynamic response prosthetic feet, with a low cost compared to carbon fibre.

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5.53

New Mechanical Flexion Lock System for Transfemoral Prosthetic Knees for Running

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BACKGROUND

Unilateral transfemoral amputees typically use a prosthetic knee for running. The function of such knee is similar to a non-friction hinge joint during stance. Therefore, those runners must acquire how to control their prosthetic leg motion to avoid falling with unintended prosthetic knee flexion. We have addressed this concern by developing a passive mechanism for a prosthetic knee. However, the mechanism that locks knee flexion with the ground reaction force (GRF) cannot completely avoid the risk of unintended flexion.

AIM

The present study proposes a new passive mechanism that locks flexion during stance regardless of the condition of the GRF.

METHOD

We designed a mechanism to enable flexion with a prosthetic leg swing and to lock flexion after a certain period. Then, if a certain magnitude of the GRF is applied to the prosthetic leg, the mechanism is set to a state that allows flexion with leg swing motion again. Therefore, the mechanism always locks flexion except during the first half of the leg swing. Then, a rough prototype was constructed to confirm the designed function, and an evaluation experiment was conducted.

RESULTS

The function of the proposed mechanism was tested with the prototype alone (i.e., not with actual amputees). The results showed that the mechanism locked flexion in the simulated stance phase regardless of the direction and magnitude of the force that was applied instead of the GRF. The mechanism then began to allow flexion with the simulated leg swing motion, with flexion allowance ending after a certain period. Finally, when a certain magnitude of force was applied, the mechanism was set to allow flexion with leg swing motion again.

DISCUSSION AND CONCLUSION

A mechanism that locks knee flexion regardless of the condition of the GRF was designed in the present study. Although tests under actual situations are necessary in our future work, the results of the present study suggest that the proposed mechanism functions appropriately under actual running conditions because the swing time is nearly constant, regardless of the running speed [1-3]. We thus proposed a new passive mechanism for transfemoral prosthetic knees for running, with the prototype functioning as designed.

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Poster Presentation
Footwear

5.54
Evaluation of Military Boots Effects on Gait Symmetry Using Ratio Index, Symmetry Index, and Gait Asymmetry Coefficient

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BACKGROUND
The majority of reported overuse injuries among military populations affect lower extremities. Even slight gait asymmetry might influence physical performance and contribute to injuries. Improving gait symmetry during military training can help to prevent injuries of the lower limbs.

AIM
Evaluate military boot effect on gait symmetry and compare three gait symmetry coefficients while walking barefoot and with military boots.

METHOD
We carried out a case-control study among sixty-six active-duty infantry soldiers. All study participants were males at the mean age of 29.7 years. Cases were soldiers with prior lower leg (knee, ankle, or foot) overuse injury during the last 6 month period (cases) and controls were free of any lower extremity overuse injuries during the same period. Participants were walking on a 5-meter long walkway while 2 Quintic cameras were recording gait. Biomechanical gait analysis was performed using Quintic v31 Biomechanics software. For gait symmetry evaluation ratio index (RI), symmetry index (SI), and gait asymmetry (GA) coefficients were calculated for stride timings during barefoot and shod conditions.

RESULTS
Gait asymmetry was observed in both groups, however, cases have shown more spread out results, see Figure 1 for details. GA and SI show the least changes in both groups; the most significant symmetry change was observed in RI values, the difference between shod and barefoot conditions was statistically significant, indicating a positive footwear effect on gait symmetry (t=-3,20(65) p=0,002).

Figure 1. Symmetry ratio index, symmetry index and gait assymetry values

		Cases			Controls		
		GA	SI	RI	GA	SI	RI
Barefoot	Mean, %	0,19	1,04	1,00	0,24	0,90	1,00
	SD	3,49	22,05	3,49	2,94	17,89	2,95
Shod	Mean, %	0,18	1,03	0,25	0,15	0,85	0,28
	SD	2,55	16,70	0,13	1,93	10,86	0,14

GA – gait asymmetry, SI – symmetry index, RI – ratio index; SD – standard deviation.

DISCUSSION AND CONCLUSION
Gait video analysis is a practical tool to identify asymmetries not only among cases but also among non-injured study participants. This study results showed positive military footwear effects on gait symmetry using ratio index, symmetry index, and gait asymmetry coefficient, however, only ratio index showed statistically significant symmetry improvement while walking with shoes.

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Poster Presentation
Paediatrics

5.55
The Provision of Sports and Activity Prostheses: The Impact on a Child/Young Person's Activity Levels

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BACKGROUND
Participation in physical activity has significant health benefits for people with limb difference; however, research has shown a number of barriers are preventing the prosthetic limb user from participating. In 2016, in order to maximise physical and psychosocial health, the Department of Health (DoH) England announced funding for paediatric activity prostheses. There is limited research on the full impact of this provision.

AIM
To identify whether the provision of activity prostheses has an impact on the activity level of children and young people aged 25 and under.

METHOD
A 38-question internet-based survey was distributed to participants aged 25 and under, by organisations involved in paediatric prosthetics, to obtain data about the impact on activity level, sporting engagement, health and daily life when using an activity prosthesis compared to using a standard prosthesis. Data was analysed using a mixed methods approach. Ethical approval was obtained.

RESULTS
8 subjects (5 upper limb and 3 lower limb) completed the questionnaire. 75% of respondents reported increased ability in “specific sports” and “being able to join in with friends”. Improvement was seen in health, wellbeing and daily life with 100% of lower limb respondents stating improvement in every aspect. 50% of participants showed the ambition of being an elite athlete.

DISCUSSION AND CONCLUSION
A larger sample group is required to make statistical conclusions, however responses showed large increases in sporting engagement and participation at a higher level when using activity prostheses. There was a vast improvement in the health and wellbeing of respondents, with greater changes amongst lower limb participants. Overall, the study indicates activity prostheses have contributed to increasing activity level and improving the health and quality of life of the users.

5.56
A Specialist Paediatric Neuromuscular Orthotic Clinic in an NHS Trust

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BACKGROUND
Orthotists play an important role in the management of paediatric neuromuscular conditions [1]. Limited data is available on orthotic clinics, and the details of orthotic treatment provided to children with neuromuscular conditions, however.

AIM
This study aimed to gather baseline data on a neuromuscular orthotic clinic in a specialist children's hospital neuromuscular service setting. The service treats spinal muscular atrophy (SMA), muscular dystrophies, congenital myopathies, hereditary neuropathies and related conditions.

METHOD
This study was classed as a service evaluation and was registered with the local audit office (reference 2732). Data was retrospectively reviewed for clinics during a 16-week period in 2019. The data reviewed included patient diagnosis, orthosis provided, appointment durations and use of outcome measures (OMs).

RESULTS
A total of 16 different neuromuscular conditions were seen; the most frequent were SMA type 2 (24%), SMA type 1 (22%) and congenital myopathy (12%). The most frequently provided orthoses were thoraco-lumbo-sacral orthoses (TLSOs) and knee-ankle-foot orthoses (KAFOs) (36% and 31% respectively). Four patients with SMA 1 or 2 were prescribed hip-knee-ankle-foot orthoses (HKAFOs) or thoraco-lumbo-sacral-hip-knee-ankle-foot orthoses (TLSO-HKAFOs) (3%). Complex orthoses (KAFOs, TLSOs, HKAFOs and TLSO-HKAFOs) were more frequently provided in children with SMA compared to all other diagnoses (Fisher's exact test, p=0.0014). Mean appointment duration was 44 minutes (range 30-70). Mean appointments per year per patient was: 2.9 (range 1-9) for all children; 4.2 for SMA; 2.2 for all diagnoses except SMA. An OM relating to the treatment goal was used in 47% of patients including gait speed, Cobb angle and joint range of motion.

DISCUSSION AND CONCLUSION
The orthotic management of neuromuscular conditions in a specialist clinic is described. Data from another NHS children's orthotic clinic reported only a 2% caseload of similar dystrophies and neuropathies and 3% TLSOs and KAFOs [2]. The previous study also reported shorter appointments (mean 27.4 minutes) compared to this service. These findings highlight the complex orthotic needs of children with neuromuscular conditions. Further research is needed on orthotic management in this group.

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5.57

Adolescents with Congenital Limb Reduction Deficiency - Perceptions of Treatments during Childhood and their Views of Current Situation and Future

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BACKGROUND
Selection of early treatments for children with congenital limb reduction deficiency (CLRD) are often decided by the parents and health care professionals [1]. Usually, the outcomes of these early treatments are quantitatively reported in terms of body functions, ease of activities, and participation in daily environment. In this study, we aim to broaden this picture by giving a voice to the adolescents with different forms of congenital limb reduction deficiency (CLRD).

AIM
The aim of this study is to describe perceptions of treatment received during childhood and their thoughts of current situation and views of future, in adolescents with CLRD.

METHOD
The study had a qualitative design using semi-structured interviews. Participants were recruited through purposive sampling from three specialist units for children with CLRD in Sweden. Adolescents, 16-20 years, with some type of CLRD, and treated from about 1 year of age were included. Interviews were conducted with 10 adolescents, 4 boys and 6 girls, mean age 17.6 years. Data was analysed applying a phenomenographic research approach inspired by Marton[2]. The investigation is directed at the variation in the adolescent's perspectives of treatment of CLRD during childhood.

RESULTS
The early treatments described by the participants have been offered and implemented by health care professionals in Sweden, at national and regional level. By compiling the participants' descriptions, early treatments of CLRD are identified as surgery, assistive devices, and training.

The ongoing data analysis results preliminary in an identification of eight categories describing variation of the adolescent's perceptions of treatment during childhood. Categories describing perception of treatment during childhood are c*reating prerequisites, learning in treatment,* and *belonging in a context.* Categories describing perception of treatment during childhood in relation to thoughts of the current situation are *just keep going*, *not now – but opportunities ahead,* and *opted out - no need anymore*. Categories describing perception of treatment during childhood in relation to views of future are *being in some uncertainty* and *being in control*.

DISCUSSION AND CONCLUSION
The treatment received during childhood has, for the participants in this study, contribute with prerequisites of importance for their ability to shape their lives in different directions.

Conclusion: Through patients' own perspectives on treatment of CLRD during childhood, this study contributes to a broader knowledge of early treatment of children with various forms of CLRD.

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Poster Presentation
Psychosocial Issues / Quality of Life

5.58
Long-Term Home Use of a Lower Extremity Sensory Neuroprosthesis: A Qualitative Case Study

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BACKGROUND
Currently available lower-limb prostheses do not provide direct sensory feedback about foot-floor interactions. Recent advances in neurotechnology have demonstrated the feasibility of sensory restoration to individuals with limb loss[1,2]. However, the benefits of such sensory feedback have not been studied outside of controlled laboratory environments. Long-term autonomous use of such prostheses in home and community settings is necessary to determine the effects of sensory feedback on locomotion and psychosocial outcomes.

AIM
To qualitatively characterize the subjective experiences of utilizing a lower limb sensory neuroprosthesis at home and in the community.

METHOD
A 68-year-old male with unilateral transtibial amputation received a sensory neuroprosthesis (SNP) that electrically stimulated his peripheral nerves to elicit sensations perceived as arising from the missing limb. The study consisted of 31 weeks of autonomous home use of the SNP, during which five semi-structured interviews were conducted at key intervals. Transcribed audio was analysed with a modified grounded theory approach using constant comparison methods. Two analysts conducted open and axial coding with consensus, and all codes and decisions were discussed with an auditor.

RESULTS
Open coding of the transcribed audio identified 23 distinct codes describing a wide range of reported experiences. Of specific note were the nodes' Stimulation Parameters' which described the intensity of the electrical currents delivered to the nerve self-selected by the participant and 'Strategies for Locomotion,' which discussed how the subject incorporated sensation into gait strategies. These codes suggested that low levels of electrical stimulation were perceived as optimal by the participant. At these levels, stimulation was described as pleasant and useful. Sensation allowed for the development of locomotion strategies that were employed to navigate in low visibility situations. These strategies persisted after removing sensation, demonstrating that the new strategies had been learned and incorporated into the participant's prosthesis use.

DISCUSSION AND CONCLUSION
Through qualitative analysis, we captured the priorities and functional improvements in the subject's own words. Although the participant did not report any deficits in his balance or gait at the beginning of the study, he reported marked improvements in his locomotion strategies during and after SNP use. Our analysis also revealed that the stimulation paradigm directly affected perceived sensations, and reported benefits became apparent only after the participant found his preferred paradigm.

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5.59

The Similarities and Differences of Living with Knee Disarticulation and Transfemoral Amputation

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BACKGROUND
Knee disarticulation amputation (KDA) is infrequently used despite its theoretical advantages over transfemoral amputation (TFA). KDA offers a longer residuum with the potential to end weight-bear and self-suspend the prosthesis, unlike TFA. However, a good cosmetic finish is difficult to achieve with KDA. KDA and TFA have previously been compared in terms of wound healing and limb fitting[1,2,3] but the lived experience from the patient's perspective has never been explored.

AIM
To explore the experience of living with KDA or TFA, specifically prosthetic satisfaction, perceived body image, and overall quality of life and compare the experiences of the two groups.

METHOD
A cross-sectional qualitative study using face-to-face and telephone semi-structured interviews. Interviews were directed by a topic guide, audio recorded and transcribed verbatim. Participants were recruited from two artificial limb centres. A sampling frame was used to find 12 community-dwelling participants with KDA. A similar number of male and female, with high- and low-level mobility, was sought. Recruitment of TFA with matched characteristics is ongoing.
Thematic analysis with an inductive approach will be used to draw conclusions from the data. Conception of themes and comparisons between groups are ongoing.

RESULTS
A developing theme is "looking normal"; some with KDA prioritise a prosthesis that is easier to disguise and would sacrifice more advanced componentry to achieve this. Others want their amputation to be obvious, especially when using accessible facilities.
Another early theme is the "burden of amputation"; participants with KDA describe a constant awareness of their risk of falling, despite having had relatively few falls. Subthemes include living with phantom sensations and forward planning to complete simple daily tasks.
Non limb-wearing KDA participants describe key advantages of end weight-bearing such as kneeling when gardening, getting out the bath, or for balance and support when using a stand turner. Limb-wearers who successfully end weight-bear would not sacrifice this function in order to achieve a better cosmetic appearance from even knee centres.

DISCUSSION AND CONCLUSION
This study will add to our understanding of the experiences of people with KDA and TFA by directly comparing their lived experience. Comparisons will focus on cosmetic satisfaction, end versus ischial weight bearing, and function when not limb wearing to assess what impact these factors have on lived experience. Previous quantitative studies comparing KDA and TFA have conflicting conclusions[4,5,6]. This study provides unique insight into the suitability of future prospective trials comparing KDA and TFA.

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5.60
Do Aesthetics Matter in Prosthetics?

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BACKGROUND
The concept of aesthetics often appears to be an after-thought when producing a prosthesis. Although literature frequently considers aesthetics there is limited research into aesthetics of prostheses specifically.

AIM
Review the literature regarding aesthetics in terms of prosthetics.

METHOD
A Boolean combination of relevant key words was used in a search of five electronic databases, Web of Science (Core Collection), ProQuest (Biological Science Index), PubMed, APA PsychInfo and Google Scholar. Full text publications were selected according to relevant inclusion and exclusion criteria. The resulting papers were then ranked using the Scottish Intercollegiate Guidelines Network (SIGN).

RESULTS
26 papers were selected for review. Key themes included, mental health, personal identity, expression and fashion, aesthetic options, culture and geography, gender and relationships, and limb absence level or cause.

DISCUSSION AND CONCLUSION
This study area is extremely subjective, which, combined with small study groups, caused few statistically significant conclusions quantitatively and some contradictions qualitatively. Longitudinal studies would be of benefit in this area, but few have been carried out. Recommendations are made for further research, exploring gaps discovered in the literature. The mental health impacts in terms of the need for societal acceptance and self-expression are prominent themes.

Poster Presentation
Outcome Measurements

5.61
Structural Validity of the modified Trinity Amputation and Prosthesis Experience Satisfaction Subscale in a sample of Upper Limb Amputees

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BACKGROUND
The Trinity Amputation and Prosthesis Experience (TAPES) Satisfaction scale was developed for lower limb amputees.[1] Its structural validity was examined and scoring modified for upper limb amputees (TAPES-Upper).[2] Given the single study on structural validity, research is needed to confirm the factor structure. Without validation, clinicians, regulators, payers and researchers cannot select or utilize appropriate outcome metrics, and the needs and function of female Veterans ULAs cannot be evaluated carefully.

AIM
Modification of the TAPES-Upper to incorporate issues of concern to women, and evaluation of the structural validity and reliability of the revised measure.

METHOD
We conducted a telephone administered survey of 671 participants (133 women and 438 men) with major upper limb amputation, preceded by a pilot study for measure refinement. Fifty persons completed the survey twice within two weeks. We performed exploratory factor analyses using data from the first 319 participants, and confirmatory analyses with data from the next 352 persons. Rasch partial credit modelling using data from the full sample evaluated differential item functioning (DIF), person and item reliability, and internal consistency. Finally, d test-retest reliability was examined using a subsample of 50 persons who completed the survey twice. Minimal detectable change was calculated at 90% confidence (MDC90) using test-retest reliability estimates.

RESULTS
Exploratory and confirmatory factor analysis indicated a two-factor solution. After dropping items with differential item functioning in Rasch partial credit models, there was acceptable model fit in both a 4-item Cosmesis factor (CFI=1.000, TLI=1.000, RMSA=0.007) and a 6-item Function factor (CFI=0.994, TLI=0.990, RMSEA=0.085). DIF by age, gender and prosthesis use was negligible for all items. The Cosmesis factor's Rasch person reliability was 0.81 and item reliability was 0.95, while for the Function factor, person reliability was 0.88 and item reliability was 0.98. Cronbach alpha was 0.84 for both factors, and ICC(3,1) was 0.70 and 0.72 for the Cosmesis and Function subscales, respectively. MDC90 was 13.2 and 11.4 for the Cosmesis and Function subscales, respectively.

DISCUSSION AND CONCLUSION
The final TAPES satisfaction subscales use 9 of the 10 original TAPES satisfaction scale items. A new item, flexibility, replaced the comfort item. The Cosmesis and Function subscales have sound structural validity, good internal consistency, good to excellent reliability, and moderate test-retest reliability. These subscales have been validated in a sample with a large number of women, and there was no difference in the functioning of any item by gender.

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5.62

Validation of the modified Trinity Amputation and Prosthesis Experience Psychosocial Adjustment Subscale

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BACKGROUND

The Trinity Amputation and Prosthesis Experience Scale (TAPES) was originally developed for persons with lower limb amputation who use prostheses and includes a Psychosocial Adjustment section.[1] The TAPES was later modified for use with persons with upper limb loss.[2] Eleven of the 14 original TAPES Psychosocial Adjustment items refer to the use of “an artificial limb”, making them inappropriate for persons with amputation who do not use a prosthesis.

AIM

Modification of the Psychosocial Adjustment subscale of the TAPES by adding items applicable for persons who do not use a prosthesis, and assessment of the psychometric properties of the modified scale.

METHOD

We administered a telephone survey to 727 persons with major upper limb amputation, after pilot testing. Fifty persons completed the survey twice within a week. Initial exploratory and confirmatory factor analyses (EFA and CFA) used data from the first 351 persons and final CFA was based on the subsequent 376 respondents. The full sample was used in Rasch analyses to evaluate item fit statistics, item category curves, and any differential item functioning (DIF). We examined item-person maps, score distributions, and person and item reliability. Test-retest reliability was assessed with intraclass correlation coefficients (ICC).

RESULTS

EFA and CFA indicated a two-factor solution. After dropping items with moderate to severe DIF in Rasch partial credit models, there was acceptable model fit for a 7-item Adjustment to Limitations factor (CFI=0.96, TLI=0.95, RMSEA=0.128) and a 9-item Work and Independence factor (CFI=0.935, TLI=0.913, RMSEA=0.193). Despite high RMSEA, the ratio of eigenvalues indicated unidimensionality. Good item fit was observed, and item difficulties sufficiently covered the range of person scores in Rasch item-person maps. Person and item reliability were 0.70 and 0.95 for the Adjustment to Limitations subscale, respectively, and were 0.87 and 0.99 for the Work and Independence subscale. Cronbach alpha was 0.82 and 0.90, and ICC(3,1) was 0.63 and 0.80 for the Adjustment to Limitations and Work and Independence subscales, respectively.

DISCUSSION AND CONCLUSION

The analysis identified two psychosocial adjustment subscales: Adjustment to Limitations and Work and Independence subscales with sound structural validity, good person and item reliability, and moderate to good test-retest reliability. Both scales can be used for persons with upper limb amputation regardless of whether they use a prosthesis.

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5.63
Functional Capacity of Individuals with Brachial Plexus Injury

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BACKGROUND
More than half of the individuals with brachial plexus injury (BPI) experience musculoskeletal complaints (MSC) [1]. Individuals with BPI may be more prone to develop MSC, given that limited functionality in one upper limb increases the load on the unaffected bodily structures. As a consequence, individuals with BPI may require a higher functional capacity (FC) compared to two-handed individuals to enable (pain free) functioning.

AIM
To compare the FC of individuals with BPI and controls. Secondary aims: to explore differences in FC of individuals with BPI (1) with and without hand function (2) for the affected and unaffected side (3), and with and without MSC.

METHOD
23 individuals with BPI and 20 healthy controls, aged between 18-65 years, performed the FC evaluation tests adjusted for the use in 1-handed individuals (FCE-OH). The FCE-OH consists of 6 tests, 2 two-handed tests and 4 one-handed tests [2]. Hand function was assessed via a physical examination; a questionnaire was used to assess MSC. FCE-OH test results of individuals with BPI and healthy controls were compared using Mann-Whitney U tests. Test statistics and effect sizes (r) were determined. Descriptive statistics and box plots were used to explore the secondary aims.

RESULTS
Individuals with BPI scored lower on the two-handed tests, as compared to controls (overhead lifting test two-handed $p=0.00$ $r=-0.59$; overhead working test $p=0.01$ $r=-041$). When individuals with BPI used the unaffected side, their performance on the one-handed test was similar to that of the dominant hand of controls. Their performance was worse when using the affected side. Results did not differ between individuals with or without function of the affected hand, except in the two-handed overhead lifting test, where overhead lifting capacity was lower for individuals without hand function. Test results were similar for individuals with BPI with (n=11) or without MSC.

DISCUSSION AND CONCLUSION
Two-handed FC in individuals with BPI was lower than that of healthy controls. The finding that FC of the unaffected side was similar to the dominant side of healthy two-handed individuals might reflect a relative capacity deficit of the unaffected side. MSC were not associated with lower FC.

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5.64

Measuring Shear Strain of the Plantar Aspect During Gait using Digital Image Correlation

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BACKGROUND

Diabetic ulceration costs the NHS approximately £1.13 Billion annually [1], with this figure set to rise with increasing diabetic populations. Pressure contribution to ulceration is comprehensively researched, with strain often overlooked due to difficulties quantifying shear during foot interactions. The application of digital image correlation (DIC) methods to quantify soft tissue strain is an emerging field and offers scope to measure plantar surface strain as demonstrated by Ito et al. [2].

AIM

To develop a DIC measurement methodology appropriate for in-clinic use to provide detailed plantar surface shear strain measurements during ambulation.

METHOD

DIC is based upon tracking deformation of a stochastic pattern. A low ink transference Indian ink and rubber stamp application was developed for plantar patterning. Patterns were generated and assessed using commercially available DIC software (Correlated Solutions Speckle Generator [3], GOM Correlate [4]). A raised walkway with high-resolution (1080x1920) webcam facilitated single step plantar analysis for 2D shear strain mapping, calibrated using a multi-image checkerboard. Ambulatory right foot surface strain measures were taken respective to a neutral standing position.

RESULTS

Low ink transference stamping was found to be quick, reliable and offers promise for clinical environment use. Pattern evaluation identified a 1.25 mm diameter, 75% density and variance speckle for best performance at study observed plantar strains. Operating the webcam at 30fps tracked stance and gait phases with appropriate clarity to allow 2D DIC analysis of surface strain. Right foot plantar surface strains were successfully tracked when in contact with the glass walkway.

Figure 1. Plantar surface strain magnitude of stance comparative to standing: a) quiver plot b) heat map.

DISCUSSION AND CONCLUSION

Low ink transference stamping leads to fast drying with reliable repeatable patterning. The method offers a clinically appropriate approach compared to traditional spraying methods and provides a promising 2D technique for plantar studies, able to compare to pressure data to study ulcer formation. Glass contact is required for analysis, reducing the potential of full foot assessment as in 3D DIC.

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5.65

Psychometric Properties of the Patient Specific Functional Scale in Ankle Foot

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BACKGROUND
Orthotists treat individuals with a wide range of conditions. This makes the selection of outcome measures and their integration into clinical practice challenging. The Patient Specific Functional Scale (PSFS) has well established psychometric properties in many pathology- and intervention-based populations and may therefore be an appropriate outcome measure for ankle foot orthosis (AFO) users. However, it has not yet been evaluated in this setting.

AIM
To evaluate the test-retest reliability, convergent and known-groups validity of the PSFS in AFO users.

METHOD
A repeated measures study design was used with data collected at two different times. AFO users were recruited from four orthotic clinics. Participants completed the PSFS and the Orthotics Prosthetics Users Survey: Lower Extremity Functional Status questionnaire (OPUS-LEFS). Relative reliability was calculated using the intraclass correlation coefficient (ICC), and absolute reliability using the standard error of measurement (SEM) and minimal detectable change at the 90% confidence interval (MDC_{90}), respectively. Convergent validity was assessed using Pearson's correlation, and known-groups validity using the independent sample t-test.

RESULTS
To date, 52 individuals have participated in the study (N=15 female; mean age = 62 ±14.2 years). There have been 17 dropouts (lost to follow up, chose to drop out, or did not pursue treatment). The mean time between the first and second assessment was 26.3 ± 13.8 days. ICC values for the PSFS ranged from 0.58-0.83. The SEM ranged from 0.84-1.53, and MDC_{90} ranged from 2.78-5.04. Pearson's correlation between the PSFS and OPUS-LEFS ranged from 0.35-0.55. Known-groups validity was not established; there was no statistical difference between PSFS scores of individuals who used a mobility aid and those who did not ($p>0.05$).

DISCUSSION AND CONCLUSION
Adequate reliability (>0.70) was found for four of the six PSFS activities. Overall, the PSFS demonstrates initial evidence for inadequate (< 0.70) test-retest reliability and moderate (0.30-0.60) construct validity. Further evidence based on a larger sample size (n > 50), including an evaluation of responsiveness, is required prior to recommending or discouraging mainstream clinical use.

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5.66
A Digital Prosthesis Evaluation Questionnaire for More Efficient Use in the Clinic

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BACKGROUND
The Prosthesis Evaluation Questionnaire (PEQ) is a validated instrument to measure prosthesis user quality of life and functional outcomes in lower limb prosthesis users [1,2]. Since development in 1998, the 82-question paper-based PEQ has been widely used in a range of published research studies and clinical evaluations. However, while the PEQ is still valid and relevant in current times, its method of use has been updated with digital automation to save time, improve accuracy, and increase ease of use.

AIM
The purpose of this work was to create a mobile application (app) version of the PEQ that is easy to use, saves time, and improves accuracy.

METHOD
There are many ways to create the digital form of PEQ or any paper-based survey. One can make a PC-based application that runs on Mac or Windows operating system, a web-based application that runs using an internet browser, or mobile application that runs on iOS or Android operating system. We chose to develop a mobile application to allow portability. Portability provides for an improved user experience for individuals with lower limb loss since they could complete the PEQ either at the clinic or in the comfort of their home, and additionally use the mobile app without any internet service.

RESULTS
The app is published to both Apple and Google App stores. The app has the option to select a full evaluation that includes all subscales or importantly, the user can select any number of separately validated individual subscales of the PEQ for the respondent to answer. This tailoring allows the PEQ to be used in a validated way with only a few questions instead of requiring answers to the full body of the original PEQ. Each question is written identically to the paper version of PEQ, and the input method retains the visual analogue scale. Electronic touch-screen have demonstrated equivalency to their paper hard-copy counterparts for visual analogue scales [3,4].

When the survey is completed, results are calculated automatically. The clinician can instantly export the detailed PDF report for storage or electronic filing such as in the patient's medical record.

DISCUSSION AND CONCLUSION
The app currently only supports the English language. Future work will internationalize the app using existing translated versions of PEQ. We conclude that using the digital mobile app version of PEQ is easy to use, saves time, and improves accuracy.

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5.67

A Novel Clinician-Reported Outcome Measure for Assessing the Ambulatory Potential of People with Lower Limb Amputations

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BACKGROUND

Prescription of prosthetic components and their reimbursement is influenced by the functional ambulatory potential of people with lower limb amputations (PwLLAs). Ambulatory potential is typically assessed using the Amputee Mobility Predictor (AMP), which is a performance-based outcome measure. The AMP requires close proximity between the clinician and patient for facilitating the test activities and for safety purposes. As a result, AMP may not be the appropriate outcome measure for telehealth applications.

AIM

This study describes the development, reliability and validity of novel a clinician-reported outcome measure, called the Potential for Prosthetic Ambulation (PPA) scale, for assessing the functional ambulation potential of PwLLAs.

METHOD

The PPA scale is a 22-item questionnaire which assesses functional ambulatory potential using the dimensions of: motivation, physical capacity, comorbidities, condition of the residual limb and ambulation status before the amputation surgery. A sample of 10 PwLLAs was used to determine the reliability and validity of the PPA scale. For inter-rater reliability, the PPA questionnaire was completed by a physician and a physical therapist and intra-class correlation coefficients (ICC) were calculated. Concurrent validity was determined by calculating the correlation coefficient between PPA scores and AMP scores.

RESULTS

The PPA scale is a 22-item questionnaire which assesses functional ambulatory potential using the dimensions of: motivation, physical capacity, comorbidities, condition of the residual limb and ambulation status before the amputation surgery. A sample of 10 PwLLAs was used to determine the reliability and validity of the PPA scale. For inter-rater reliability, the PPA questionnaire was completed by a physician and a physical therapist and intra-class correlation coefficients (ICC) were calculated. Concurrent validity was determined by calculating the correlation coefficient between PPA scores and AMP scores. These initial study results are encouraging and demonstrate good inter-rater reliability of PPA scale and a strong correlation between PPA scores and the gold standard AMP measure.

DISCUSSION AND CONCLUSION

This is an ongoing study and the presented data on 10 subjects is a subset of 50 subjects that will be tested. The goal of this study is to test PwLLAs with different amputation levels and different functional levels to create a robust scale for clinical applications. In conclusion, the PPA scale is a reliable and valid measure for assessing the ambulatory potential of PwLLAs and is suitable for telehealth applications.

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5.68

Clinical Outcome Measures: Applicability of Current Instruments to Differentiate Functionalities of Prosthetic Components

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BACKGROUND

Clinical Outcome Measures (OM) represent performance-based or self-reported tests that assess the quality of execution of everyday movements, functional mobility, balance or quality of life [1,2]. Besides the use of OM to rate patients' functional capacity they are used to document the progress of therapy and rehabilitation or to evaluate the benefits of a component compared to another. Despite a huge amount of existing OM, their usage in amputees seems to be limited and a gold standard is still missing.

AIM

The purpose of the study was to investigate the usability of established clinical OM to display the benefits of different functional prosthetic knee joints in transfemoral and prosthetic feet in transtibial amputees, respectively.

METHOD

A set of nine performance-based OM (AMPPro, DGI, NBWT, SAI, HAI, TUG, L-Test, FSST, 6MWT) were chosen in order to display the differences of three knee joints (C-Leg4 - MPK, 3R80 - conventional controlled hydraulics and 3R92 - brake knee; Ottobock, Germany) as well as three feet (Triton - ESR, Trias - ESR, SACH - Non-ESR; Ottobock, Germany). Ten transfemoral amputees (54±6 years, 76±13 kg, 178.± 8cm) and ten transtibial amputees (52±11 years, 84±11 kg, 177.± 8cm) with mobility grade three and four were enrolled in the study to perform the set of OM with each of the three knee joints and feet, respectively.

RESULTS

Regarding the evaluation of prosthetic foot functionalities, none of the OM scores showed significant differences (table 1). In contrast, significant differences between the three prosthetic knee joints were detected for about half of the OM and especially for time related OM. Even though, those findings are extremely diminished when considering the minimal detectable change (MDC) given for a population of lower limb amputees additionally, because only two of the significant difference (TUG, 6MWT) exceed the MDC.

Outcome Measure	C-Leg - 3R80	C-Leg - 3R92	3R80 - 3R92	Triton - Trias	Triton - SACH	Trias - SACH
AMPPro	ns	s	ns	ns	ns	ns
DGI	ns	ns	ns	ns	ns	ns
SAI up	ns	ns	ns	ns	ns	ns
SAI down	s	s	s	ns	ns	ns
HAI	ns	s	s	ns	ns	ns
NBWT	ns	ns	ns	ns	ns	ns
FSST	s	s	ns	ns	ns	ns
TUG	s^+	s^*	s^+	ns	ns	ns
L-Test	s^+	s^+	s^+	ns	ns	ns
6MWT	s^+	s^*	s^+	ns	ns	ns

table 1: ns: not significant; s: significant; s^+ in bold (black): significant but below MDC; s^* in bold (red): significant and within MDC

DISCUSSION AND CONCLUSION

The limited applicability of the applied OM might be due to the fact that many of those often used OM originate from unrelated disciplines (e.g. neuro-rehabilitation) [1,3,4]. This might lead to OM items that are not designed for the specific needs of amputees and therefore are not sensitive enough to display functional differences of prosthetic components. Although OM are increasingly applied in the field of lower limb amputees, further research regarding a specific adaption of available OM is necessary.

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Poster Presentation
Developing Countries

5.69

Modern Service Clinic and Cost Recovery Pilot Project for the Sustainability of Prosthetic and Orthotic Service in Cambodia

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BACKGROUND
There is an increase of belief in how business innovations could make larger-scale, more sustainable impacts on societies than a traditional charitable model. However, there is no one size fits all when it comes to a solution for sustainability in prosthetic and orthotic services in LICs and LMICs. A successful model in LICs and LMICs may require triple tracks approach- multi-sectoral (the public, the private sector); multi-lateral organizations, and donor agencies-to contribute to the financial sustainability for service provision.

AIM
To means-test the feasibility of sustainability in prosthetic and orthotic rehabilitation through a blended approach with various sources of funding; government, charity, and service users through fee-for-service for affordable clients and a subsidy system for those with less income.

METHOD
The means-testing of this pilot program of CR and MSC was only conducted at one of Exceed Worldwide Rehabilitation Center in Phnom Penh, from February 2019 - January 2021.
The users made decisions on the services they would like to receive. A poverty assessment interview where a scorecard is made to determine their ability to pay for CR. Those users who said they could not afford to pay, held the ID Poor, Veterans, identified by the local authority as poor received service for free.
This study used a quantitative approach for data collection. The data is a retrospective analysis from the pilot project. The analysis was made via Excel.

RESULTS
Cost Recovery (CR) Program
2,256 clients received services, 13% were new clients, and 3% were from other centres. Approximately 2% of clients declined services.
1,171clients received charity service (for free), equivalent to 57% of the total number of clients, 53% were prosthesis users, 42% were orthosis users, 5% were wheelchair users.
Only 830 people (41%) were able to contribute between US$ 50 to US$ 100. That number was the highest compared to other numbers, ranging from 2% to 5%.

Modern Clinic Service (MSC) Program
A total of 664 clients, 502 were new (76% of the total customers), 57.5% of the total customers were orthosis users. The number of customers who came for repairing services was about 18% of the total. About 5.4 percent of customers bought prosthetic and orthotic spare parts. The smallest number was the number of wheelchair users.

DISCUSSION AND CONCLUSION
This pilot project serves as a basis for future investment and mechanisms on the sustainability of rehabilitation services. MSC has proven to be a potential innovation in the concept of Social Enterprise (not-for-profit business) where the revenue is fed back into the charity service in order to sustain free care for the poor. Both MSC and CR services are seen as feasible approaches to improve the long-term sustainability of rehabilitation services in emerging middle-class communities through blended approaches.

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Poster Presentation
Healthcare Policy and Services

5.70
Assistive Technology Demands in Algarve (Portugal)

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BACKGROUND
10 to 20% of the European population present some degree of disability and the aging population tend to acquire some degree of disability, reinforcing the need for assistive technology (AT). Portugal has one of the highest aging index in Europe and 22% of Portuguese population (≥ 65 y) present difficulties in self-care and 50% difficulty in home activities. AT promotes autonomy, reduce physical barriers and has a positive psychosocial impact. Main barriers to AT access include architecture, know-how, information, funding or politics.

AIM
The purpose of the study is to develop a systematic review of the population characteristics and assistive technology provision in the region of Algarve (Portugal).

METHOD
We reviewed scientific works, research papers and governmental reports from 2011 to 2019, using assistive technology, rehabilitation, mobility, Portugal, Algarve, aging, and access as key words.

RESULTS
Algarve has about 440,000 inhabitants, representing 4.5% of the Portuguese population, but has a percentage of 21.4% of subjects who are 65 or more years old. According to the Social Security data for AT access, between 2017 and 2019, AT for mobility represented 41 to 55% of AT giving per year. In a closer look, the same reports indicated that subjects ≥65 years old represented 30% to 24% of AT demands in Algarve, compared to 41% to 12% in Porto and 24% to 15% in Lisbon.

DISCUSSION AND CONCLUSION
It is estimated that ≥65-year-old population will rise 14% to 25% until 2050. Algarve presents one of the highest aging indexes in Portugal, where AT demands might grow and require a specific strategy, mainly on prosthetics, orthotics, and mobility aids. A better AT provision strategy might be important for healthy aging policies. To conclude, the aging tendency might require a more specific and integrated access to AT to reduce aging disabilities, promote quality of life and healthy aging.

5.71

A Physical Rehabilitation Project Overview in a Fragile and Conflict Affected Country during Covid-19 Pandemic

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BACKGROUND

Most persons with disability in Sudan struggle to access acceptable quality physical rehabilitation services (PRS). ICRC provides the National Authority for Prosthetics and Orthotics, Khartoum and seven state centres with continuing clinical and technical support, imported materials, components, equipment, enabling them to provide PRS including P&O devices, physiotherapy and mobility solutions. Even so, this represents less than an estimated 5% of PRS needs, according to database derived from World Report on Disability[1]: WHO and Central Bureau of Statistics, Sudan[3].

AIM: The aim is to review the database to gain an understanding of the challenges of access and quality of physical rehabilitation program in a socially, politically and economically inequitable context in Sudan, within the current COVID-19 pandemic situation.

METHOD

The ICRC Physical Rehabilitation Project (PRP) has contributed to enhance quality of existing services to retain minimum standard technology for P&O service provision, however the ongoing pandemic has exacerbated significant challenges along with civil unrest and widespread flooding. Periodic monitoring and review of quantitative statistics of overall physical rehabilitation services were exercised in Sudan for the duration of pandemic outbreak, followed by situation analysis of the physical rehabilitation project. Support outcomes and challenges were sought from different ICRC supported structures in Sudan based on SWOT analyses, which were taken into consideration for this overview. Service quality evaluation of the multi-disciplinary approach was studied and any time specific obstacles identified.

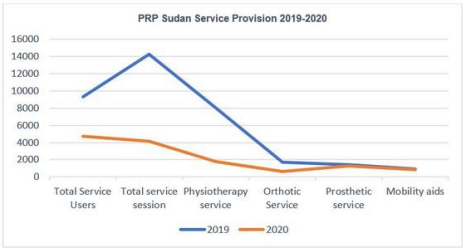

Figure1. PRP Sudan Service Provision 2019-2020

RESULTS

The quantitative statistical database extracted from the patient management system has shown a decreased number of services due to temporary closure of structures and unavailability of skilled human resource to meet the demand and therefore, an accumulation of wait listed service users were reported. A total of 4,735 service users were seen by PRS in 2020 throughout Sudan with the support of ICRC. This indicates a downturn of 47% when compared with the preceding year. Whilst adhering to the country`s post pandemic service resumption guidelines a reduction of 78% of physiotherapy services was seen, as well as a 63% reduction of orthotic services, however only 11% and 5% reductions for prosthetic services and mobility solutions were noted[2].

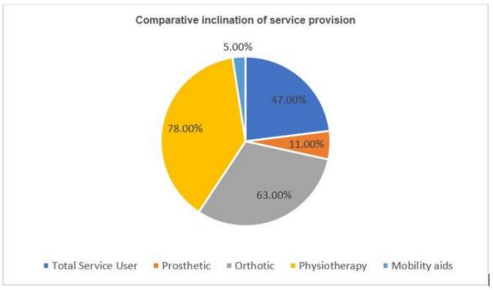

Figure2. comparative inclination of service provision

DISCUSSION AND CONCLUSION

The population of Sudan have all have passed through numerous unfavourable occurrences throughout the period of ongoing pandemic, moreover political unrest, inadequate human resources, deprived attention to physical rehabilitation services are added hurdles in a conflict impacted country like Sudan. Temporary re-allocation of human resources and ongoing technical support are subsidizing the administrative and technical gap; however, brain drain of skilled professionals and poor employment benefits will remain major challenges for physical rehabilitation services in Sudan for the foreseeable future.

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ACKNOWLEDGEMENTS: ICRC-PRP (Tigran Betanian, PRP-Manager, Sudan & Rowan English, Education Advisor), beneficiaries, partners, stakeholders for their support, cooperation even in adverse circumstances.

Poster Presentation
Education

5.72
Ottobock Blended Learning Certification Program for Internal Product Trainers

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BACKGROUND
With C-Leg market launch 1998 Ottobock started to qualify internal product trainers to multiply knowledge and certify customers on sophisticated mechatronic products. Over the years the Ottobock Global Academy established a comprehensive education curriculum for thirteen different products to raise and ensure fitting quality worldwide. With Covid-19 the face2face (F2F) based training curriculum was rearranged to a Blended Learning program with a significant amount of digital parts to ensure trainer availability and high-quality patient fittings even during this pandemic situation.

AIM
In this session the experiences of transitioning a F2F curriculum for trainer qualification for C-Leg, Genium, Kenevo & Meridium into a Blended Learning format are shared so that stakeholders in O&P education can benefit from our know-how with digital learning.

METHOD
A total of eight days of F2F training was transitioned into four well balanced modules (Module 1-3: digital / Module 4: F2F). The digital modules have been split in separate general and product-specific online sessions executed via “Webex Events” (Cisco) over several weeks. Small groups, supervised homework, and an online presentation of a practical patient case study from every trainer candidate ensured that our high training standard could be maintained also in the digital environment. After successful completion of the digital modules a temporary trainer status was granted. The final F2F module in addition to the conducted training practice represented the last step in becoming an official Ottobock product trainer.

RESULTS
The expectations in this pilot have been clearly fulfilled. Though our limited experience with such extensive online trainings and stumbling blocks like different time zones, technical challenges, and limited software tools more than 10 trainer candidates have successfully completed the program. To retrieve also quantitative feedback from the enrolled candidates an online questionnaire (1: strongly disagree - 5: strongly agree) was conducted:

1. Blended learning is the future for trainer education… Result: 3.8
2. The used IT tools have been sufficient… Result: 3
3. The digital blocks had a suitable length… Result: 4.2
4. The presented knowledge was valuable… Result: 5
5. I feel well prepared for my future trainer role… Result: 4.3

The pilot showed that certain topics can’t be trained solely digitally but a split of 60% digital and 40% F2F seems reasonable regarding our requirements.

DISCUSSION AND CONCLUSION
Next to the benefits of digital learning like repetition due to recordings, flexibility and reducing business trips there are also drawbacks like technical issues, different time zones and the lack of physical presence. Due to the positive feedback we will permanently use a Blended learning approach for future trainer education even if Covid-19 pandemic is mastered. Especially for far away countries this format will not only save resources but also lead to a more sustainable education and better qualified trainers.

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5.73

Teaching in Prosthetics and Orthotics B.Sc.: Challenges and Strategies during Covid-19 Pandemic – Case Study

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BACKGROUND
University of Algarve Prosthetics and Orthotics B.Sc. (P&O_BSc) presents 3300 contact hours, including 720 of health content, 555 specific Prosthetics/Orthotics practice and a minimum of 1200 of clinical practice. P&O_BSc has 3 years of classes and the last year in clinical practice in Portugal of other European countries by Erasmus+ cooperation agreements. Face-to-face classes were interrupted between March and September of 2020 and January and March of 2021 and b-learning strategies adopted.

AIM
The purpose of the study is to develop curriculum adaptations in P&O_BSc practical classes and clinical practice during Covid-19 pandemic.

METHOD
10 students during academic year of 2019/2020 and 2020/2021. Development of blended-learning approach, follow-up, videoconference meetings during clinical practice and research projects improvement

RESULTS
Prosthetics and Orthotics practical classes were developed using video materials regarding practical activities, videoconference classes and a literature review of techniques improvement. Final evaluation was developed using teaching platforms and online exams.

Clinical practice was developed in close contact with students and advisors, students preferred clinical placements in Portugal and just one clinical practice was developed by Erasmus+. Clinical practice oral discussion was developed using videoconference.

DISCUSSION AND CONCLUSION
Covid-19 pandemic required an adjustment in the P&O_BSc education process and the adaptation of the practical teaching methods with e-learning process, required a close attention and guidance during clinical practice. These adjustments were important to allow P&O_BSc conclusion, respecting pedagogical, scientific, and technological standards required. In the future, with similar scenarios, we consider the possibility of curriculum adaptations for b-learning, with condensed practical activities, more self-study and autonomy searching written works to complete the syllabus.

5.74

The Shift of Focus and Development of Prosthetic and Orthotic Teaching Methods Impacted by Covid Pandemic in Cambodia

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BACKGROUND
Core clinical and technical competencies for prosthetists and orthotists; and technicians are essential for their professional interaction, intervention, and performance. ISPO recognised training programmes embrace the importance of both theoretical and clinical practice during the training, ascertaining that the students develop well-round professional skills. The pandemic has impacted the usual methods of teaching delivery as success of the training programme is resulted from the instructional methods, teaching capability and learning aptitude of the students in both controlled and extra-curricular activities.

AIM
This paper presents innovative changes and responses made by the Department of Prosthetics and Orthotic in Cambodia to maintain the quality of education for Associate Prosthetists and Orthotists, and technicians throughout the pandemic.

METHOD
15 teaching staff and 24 students at the Department of Prosthetics and Orthotics (DPO), Cambodia involved with curriculum modification, teaching challenges focus group discussions, student satisfaction surveys from March 2020 to February 2021. The Management Team of DPO collected this qualitative feedback and modified the curriculum, teaching delivery methods, and identified training needs for all educators. Training plan for both faculty and students were made to ensure mutual improvement and adjustment for online and blended education are well received by both parties; students and teachers. Management Review Activities and Risk Management have been served as effective tools to mitigate potential quality and course delivery methods.

RESULTS
The pandemic has resulted in the establishment of the ExceedOnline Committee where overall online teaching quality is monitored through the quality of video review, teaching methods monitoring, review of Learning Management System (LMS), curriculum modification for online mode delivery, and blended education approach.

The collaboration with other online teaching experts such as Human Study and National Institute for Digital Learning to enhance teaching and learning focus.

The use of local technical mentors at the local prosthetic and orthotic clinic/workshop to support clinical and technical competencies based on DPO requirements for the students where they are stranded in the country of origin.

Training plan for educators and students on how to adapt and adopt the online teaching and learning capability and potentials.

Making individual support for students facing challenges with an internet connection, communication difficulties, lack of local mentor support.

DISCUSSION AND CONCLUSION
Online education is seen to be positive and innovative responses to the pandemic. Virtual mode of learning, blended education, and innovative professional clinical practice arrangement are considered potential solutions for the future enhancement of universal need coverage for the current and rising demand for prosthetic and orthotic care worldwide. However, ISPO should consolidate the teaching methods and course delivery through online mode for recognised schools to enhance the confidence, trust, and assurance of the quality of the training programmes.

ACKNOWLEDGEMENTS: Thanks to the Nippon Foundation for the support on the delivery of online PO education at Exceed Worldwide's schools. Special thanks to educators, students, and Management of Exceed Worldwide and DPO for the commitment to make a difference and also maintain the quality of ISPO Standards.

5.75
Tools to Assess Psychomotor Learning: What do Students Think?

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BACKGROUND
Orthotic and prosthetic (O&P) students complete projects that require the use of hand skills, mechanical reasoning and problem solving. The learning objectives for these projects include thinking through and performing the techniques so they may be applied to a variety of contexts. Questioning, checklists and self-reflection enhance student learning[1] and are used to encourage understanding of the underlying O&P principles. However, little evidence of tools to enhance psychomotor learning exists in O&P.

AIM
Assessment tools play a role in facilitating learning. The purpose of this project is to gather students' feedback on two different assessment tools to evaluate and enhance psychomotor learning.

METHOD
Two tools[2,3] to evaluate and enhance psychomotor learning were revised to include O&P specific items, e.g. technical fitting criteria, performance, consequences and suggestions to address the client's functional needs. Next students and faculty at two different programs will use both tools to evaluate student performance and course projects. Students and faculty will complete questionnaires on the clarity of the sub-items within the tools, the depth at which they address the mechanical principles, prior planning, the O&P technical fitting criteria, and the functional needs of the client as well as the extent that the tool assesses student psychomotor learning.

RESULTS
One faculty member used the first tool to evaluate students' performance, including their technical outcomes and proposed solutions. The second tool was used in a second course. After using both tools, students will complete a questionnaire to provide feedback on the clarity and which items in the tools most facilitated their techniques, thinking about the techniques and application to other settings. The survey results will be forthcoming in three months. We anticipate that students will prefer the second tool due to its simplicity.

DISCUSSION AND CONCLUSION
Faculty use questioning, checklists and self-reflection to improve student learning and encourage the transfer of principles and techniques to a variety of contexts. We hypothesize that use of a 'What, So What, Now What' project critique tool, with O&P specific sub-items, may facilitate deeper psychomotor learning. Student input on assignments improves the questions that faculty ask. Further work is necessary to understand if questioning and self-reflection enhance learning of underlying principles and techniques in O&P.

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5.76
oandpvideos.com

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BACKGROUND
Recognize the need for a free, widely available, professionally vetted source of video materials for O and P professionals, students, patients, therapists, and instructors using the resources of youtube technology.

AIM
Create an online directory of OandP resources based on links to professionally vetted, non-proprietary video materials listed on youtube and presented in a searchable manner. The topics included would range from fitting techniques to fabrication to patient instruction, etc.

METHOD
Establish a prototype oandp.com website and supporting spreadsheet using youtube links. Posted youtube links would be required for material to be included.
Initially contributed links would be added to a spreadsheet to be vetted by certified professionals. Once approved the links would be moved from the spreadsheet and listed on the main website according to subject matter. Access to modifying the website and spreadsheet would be limited to vetted professionals. Promotion of proprietary materials would be excluded.

RESULTS
A test model oandpvideos.com website and spreadsheet were created. The use of youtube link structure is beneficial due to its familiarity, accessibility, data retrieval, and multilingual capacity. Creating, obtaining, and classifying links and materials is a challenging but manageable and promising project. The benefit of having easily accessible (vetted) visual resources for O&P professionals, technicians, therapists, patients, and teaching resources is self-evident especially considering the problems of Covid prevalence.

DISCUSSION AND CONCLUSION
We live in a world of dynamic, rapidly expanding video potential soon to include virtual reality. Our profession needs to meet this challenge and avail itself of the opportunities it provides. An open directory vetted by professionals can avoid proprietary content and help create a more inclusive source of information helpful to all providers, therapists, and patients to better make, fit, train, and use these assistive and corrective devices.

REFERENCES
No materials discussing the structure of a website for video material could be found although Charles King CP has made a significant library of digital resources listed on oandp.com. Conversations with various schools and professional organizations involving publicly available, non-proprietary materials were unproductive.

ACKNOWLEDGEMENTS: Physicians for Peace gave me the opportunity to teach a course in Haiti and become familiar with the need for more resources to be made widely available.

5.77
Reflections on a Part-time PhD: Spinning Plates and Running a Marathon

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BACKGROUND
Continuing Professional Development is essential for health care professionals in the Prosthetics and Orthotics field. Many practitioners desire to undertake further formal study including Masters and PhD studies. It is important to support people in developing their research skills to increase the evidence base in Prosthetics and Orthotics. However part-time study whilst working, can pose a significant challenge. This paper will reflect on the author's experience of doing a part time PhD which was completed in 2019.

AIM
The aim of this paper is to highlight challenges experienced during the PhD, and detail how these challenges were managed, with a view to encouraging and supporting others who are considering further formal study.

METHOD
The author used Gibbs Reflective Cycle (1988) to facilitate reflection at several stages of the journey, and also to look back on the overall experience. The stages in Gibb's model include description, recognition of feelings, evaluation, analysis, a conclusion and an action plan [1].

RESULTS
My PhD was completed in 2019, but it was a long, and difficult process which challenged me in many more ways that I had anticipated, and often felt like spinning plates and running a marathon at the same time. The challenges included: maintaining momentum during part time study; balancing work commitments with my PhD studies; undertaking study in a different discipline; difficulties in patient recruitment; maintaining an up-to-date literature review, and imposter syndrome. The key things that helped me overcome these challenges were supportive supervisors, an accommodating employer, and an understanding family.

DISCUSSION AND CONCLUSION
Whilst completing the PhD was both a relief and a celebration, there was also a sense of loss, having reached the finish line. However the learning gained from the PhD, related not only to the new knowledge gained from the individual studies which were conducted, but also allowed the researcher to understand their own strengths and weaknesses. The author wishes to share this learning to encourage others who are undertaking further formal study.

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5.78

Understanding the Induction and Settling-in Process for Students on Prosthetic and Orthotic Practice Placements

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BACKGROUND
The practice placement is a key element of undergraduate Prosthetic and Orthotic education programmes, where students can put theory into practice. Beginning a new placement can be a daunting experience and there is a need to ensure the student is well-supported when beginning placement so that they can settle in and get the most from their experience.

AIM
To understand the induction process and the experience of a new student undertaking a Prosthetic and Orthotic practice placement

METHOD
The clinical placement co-ordinator of an ISPO approved undergraduate Prosthetics and Orthotics Programme underwent the induction process for a new placement and also attended a regular clinic for a day, in the role of student. Both the practice educator and the clinical placement co-ordinator reflected and shared their experience in order to understand differing perspectives.

RESULTS
The clinical placement co-ordinator attended an orthotic foot and ankle clinic in a local hospital, in the role of a student. Positive aspects of the experience included a clear induction process, and joining instructions, the opportunity to work with a range of clinicians and understand role of the orthotist in both inpatient and outpatient settings, and the importance of feeling welcomed by the team. Challenging aspects to the experience included managing first day nerves, trying to become familiar with several different IT systems, and the student not being accepted as an autonomous practitioner by some patients. From the practice educator's view, student supervision is enjoyable, and also challenges the clinician to develop their teaching skills and own knowledge. However, challenges include limited space to accommodate students and additional time required to explain processes and procedures.

DISCUSSION AND CONCLUSION
Greater knowledge of differing perspectives of both the ‘student’ and the practice educator about the first day experience, has helped to inform practice educator training sessions, and pre-placement briefings for students provided by the University. It has also aided in understanding some of the challenges faced by practice educators during the Covid Pandemic in relation to the student experience

Poster Presentation
Rehabilitation Medicine and Surgery

5.79
Lower Limb Prosthetic Rehabilitation Priorities: a Thematic Analysis of Prosthesis User and Clinician Interviews

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BACKGROUND
The worldwide number of individuals with lower-limb amputation(s) is expected to double from 2005 to 2050 due to ageing populations, on-going conflicts, and their landmine legacy. People with lower-limb loss are reported to have a lower quality of life and greater difficulty integrating into society.1,2 Successful rehabilitation is essential to improve their physical and mental outcomes; the psychosocial impacts on amputees' lives can be as debilitating as the physical impact.

AIM
To determine the factors perceived to impact lower-limb prosthetic rehabilitation from service users and rehabilitation clinicians to provide a basis for research, development, and policy priorities.

METHOD
Ten service user and six clinician interviewees were self-selected from a survey which aimed to identify the issues associated with lower-limb prosthetic rehabilitation. The interviews were semi-structured with questions relating to the participants' frustrations with rehabilitation and the prosthetic socket. The interviewees were asked to discuss three questions: the greatest impactor on rehabilitation; their biggest frustration with rehabilitation; and their greatest frustration with the socket. A thematic analysis was carried out to capture the information in the interviews. The following steps were implemented: familiarisation, coding, generating themes, reviewing themes, defining and naming themes, and reporting.

RESULTS
Six themes were identified: External to Prosthesis (e.g., disparity between service provision), Body Impactors (e.g. residuum volume fluctuation), Consequences of Ill Fit (e.g. socket discomfort), Prosthesis Irritants (e.g. reactions to liners), Limitations of Practice (e.g. reactive action to issues) and Work and Social Impact (e.g. inability to work). Service users mentioned prosthetic related issues impacting their work and social life, including the difficulties wearing their prosthesis all day, the socket's rigidity, and the ability to participate in hobbies. Clinicians commented on service set up, logistic and staffing impacts on quality of care, including the advantages of having prosthetic and physiotherapy teams in the same location.

DISCUSSION AND CONCLUSION
The study provides a variety of perspectives of service user and rehabilitation team priorities. Clinician and service user perspectives are coherent in most themes. The study confirms existing and provides new insights into the perceived priorities during prosthetic rehabilitation into areas that could be improved in the rehabilitation journey.

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5.80
Choosing Osseointegration: Should Prosthetists Refer to the "20/20 Dilemma"?

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BACKGROUND
Bionic solutions like bone-anchored prosthesis (BAP) connected to an osseointegrated implant could profoundly change life. However, the decision to choose the treatment could be overwhelming because of the complexity of information to consider.
Prosthetists can empower patients with critical considerations, so that educated decisions about treatments options with bionic solutions could be made.
There is need for a study outlining essential information about the efficacy and safety of BAP that prosthetists should share with their patients.[1]

AIM
This literature review presented benefits and harms of BAP, put in perspective these outcomes and suggested a balanced view of what is at stake when considering BAP.

METHOD
Literature searches focused on the role of the prosthetist in the delivery of prosthetic care for patients fitted with BAP as well as the benefits and harms of the treatment.
The methods including studies inclusion criteria, search strategies and data extraction followed essentially the protocol proposed by Vertriest et al (2017) and Pather et al (2018).[2,3]

RESULTS
Osseointegrated implants eliminate problems encountered with a socket (skin problems) and improve prosthetic use, embodiment, range of motion, sitting comfort, donning and doffing, osseoperception and walking ability that, altogether, increased quality of life by 17% compared to typical socket prostheses.[4] However, these outcomes might be overestimated because of "three boosters": placebo effect, preconceived favourable view and fitting of advanced components.
Direct skeletal attachments have little effect on phantom pain. The bone/implant coupling is prone to risks of loosening (6%), periprosthetic fractures (9%), mechanical failure of implant parts (31%) as well as deep (41%) and superficial (100%) infections that could lead to the removal of the implant in up to 20% of cases.[5] These adverse events could cause residuum pain, disturb the lifestyle and cost money.

Figure 1. Overview of the "20/20 dilemma" to resolve when considering bone-anchored prostheses (BAP).

DISCUSSION AND CONCLUSION
Based on these outcomes, prosthetists might explain to patients that considering osseointegration comes down to resolving what I call the "20/20 dilemma". The quality of life is likely to improve by 17% to 20%. The biggest risk of failure is about 20%. Patients will have, then, to determine if a bionic solution is too good to pass or too bad to grab.
The role of prosthetists in the delivery of bionic solutions has been overlooked although they prevent load-related adverse events.

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5.81
Definitive Surgical Interventions for Transtibial Amputation

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BACKGROUND
1.6 million people with limb loss were living in the USA in 2005 and the number is expected to rise to 3.6 million by the year 2050, with similar trends expected across the world (1). The goal of amputation surgery is to provide a functional residual limb with the fewest adverse effects (2). Despite the expected increase in number of amputations, there is currently no consensus regarding the most appropriate transtibial amputation technique.

AIM
To review current literature and compare Long Posterior Flap (LPF), Skew Flap (SF), Bone Bridge (BB) amputations and Transtibial Osseointegration (TOI) in regards to definitive perioperative, postoperative (acute) and functional outcomes.

METHOD
A literature review was performed in September 2020. The following databases were searched: PubMed, Science Direct, Knowledge Network, Web of Science and Embase. Studies published between 2000- 2020 were included in the literature review.

Studies with patients over the age of 18, describing at least one of the surgical techniques and reporting on at least one of the outcome measures were included.

Full text studies were assessed using “The Criteria List for the Methodological Quality Assessment” by Cochrane Collaboration Back Review Group (3). The quality of the studies was assessed and the data of each outcome measure reviewed.

RESULTS
The perioperative outcomes reviewed showed significantly longer operative and operative tourniquet use periods in BB amputations compared to the LPF amputations. There is not enough data to compare other surgical techniques.

The postoperative data showed no significant difference between LPF and SF amputations based on one available study. Only one study reported significantly greater complication rates between BB and LPF amputations. There is not enough data to make comparison between any other techniques.

The functional outcomes only showed significantly better Orthotics and Prosthetics Users Survey scores for LPF amputations compared to SF amputations. Recent studies found significantly improved Sit-to-Stand times and improved total limb work in BB groups compared to LPF groups. There are no studies comparing TOI to any other amputation technique.

DISCUSSION AND CONCLUSION
There is not enough objective data comparing described amputation techniques, because most functional outcome measures described in the studies are based on patient input. None of the included studies compared more than two amputation techniques. There is a need for prospective control trials comparing a number of surgical techniques to provide the answer for the most appropriate definitive transtibial amputation.

Currently, there is not enough research data to compare described amputation techniques in regards to perioperative, postoperative and functional outcomes.

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5.82
Complications Associated to Post-Polio Syndrome in Khyber Pakhtoonkhwa

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BACKGROUND
Poliomyelitis is a paralysis causing viral disease, which is often permanent. The delayed appearance of new or worsening disabling neuromuscular symptoms years after the original poliomyelitis attack is known as Post-Polio Syndrome. The polio survivors confront not only a range of physical disabilities but also significant social, financial and human rights barriers hindering integration and participation in families and communities. These barriers in turn lead to ill-health, social marginalization, limited access to education and employment and high rates of poverty.

AIM
This study is based on the objectives to find out complications associated to post-polio syndrome (PPS) in Khyber Pakhtoonkhwa.

METHOD
This study was done through a cross sectional survey design with sample size of n=200 that were selected through Non probability convenience sampling. The data was collected through Post-Polio Clinic Questionnaire and analysed by using SPSS 21.

RESULTS
The gender presentation among the participants was 21.50% female and 78.50% male. The total 55.5% were married, 40.5% were single and other were divorced and widows. The total 49% of the study population were having some kind of employment while the other 51% are jobless. The total 35% of sample feel some kind of physical and health changes. Out of this 35%, the (n=39) subjects feel some kind of physical changes due to new muscles weakness, the (n=25) subjects were complaining of arthritis, while (n=7) answered as they had a physical injury earlier.

DISCUSSION AND CONCLUSION
Disability education is the need of today's world, this study shows a better result regarding education but we need further progress. It is clearly concluded from this study that assistive devices have a major role in improving the Quality of life by improving physical activities. Polio survivors have some kind of change to improve the life style and most of them were satisfied with such changes.

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5.83
Remote Rehabilitation- a Desperate Measure or a New Opportunity?

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BACKGROUND
Different availability of rehabilitation care, a difficult epidemiological situation, and progress in medical and technical knowledge provide a powerful incentive for the development of remote (including online) forms of interaction with the patient.

AIM
We aimed to create an online ecosystem that accompanies the child and the family from the moment of making a decision about prosthetic until the moment of confident use of the device.

METHOD
To create an accessible in any conditions and yet full of modern and useful information ecosystem for children requiring upper limbs prosthesis we choose an online interaction. Thought chatbot families received age-specific:

1) recommendations on physical and psychological preparation for prosthetic
2) informational videos from a medical specialist about the effect of a prosthesis on health and the stages of getting used to the device
3) online group sessions with a kinesiotherapist
4) webinar with a clinical psychologist to analyse of the most common problems
5) 2-week age-specific homework with daily tasks and games with the prosthesis
6) opportunity to get in touch with a doctor to receive individual consultation

RESULTS
We have tested the system with the experts in rehabilitation and prosthesis development as well as with the adult users of the upper limb prosthesis of different types. According to the received survey forms obtained so far remote rehabilitation ecosystem is able to provide significant help in getting adjusted to the device and in gaining new skills, needed in activities of daily life. Yet the research with actual users – children of all ages - is yet to come.

DISCUSSION AND CONCLUSION
Further data is being collected to gain and prove the results of online rehabilitation with children of different ages. However, the technology seems to be promising to solve problems of different access to rehabilitation help and lack of information about rehabilitation with the prosthesis.

Poster Presentation
Gait and Balance

5.84
A Tool That Identifies Who Needs to Enter into a Gait Adaptability Training Program

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BACKGROUND
Ability to adapt gait and respond to changes in environment is important for safe locomotion. Ageing and some conditions such as lower limb amputation impair adaptable gait and increase the incidences of falling [1-3]. The association between falls and impaired step length adaptation has revealed the importance of including a gait adaptability test in the traditional assessment of risk of falling [4].

AIM
To present a novel tool, which incorporates a variety of walking tasks and adjustable targets, for identifying people with impaired gait adaptability who need interventions.

METHOD
Twenty-seven older adults with no history of falls and cognition issues were fitted with customised footwear with retro-reflective markers. A novel tool randomly and unpredictably presented one of four conditions in the gait adaptability test: (i) shortening one stride, (ii) lengthening one stride, (iii) crossing an obstacle (5 cm height), and (iv) walking through. A motion capture system and force platforms collected kinematic and kinetic data. Participants were grouped into the Touched Obstacle group (TO) and the Non-Touched Obstacle group (NTO) after they completed tests. Step length, velocity and double support time in baseline and foot-ground height, adapted stride length and velocity in the adaptability test were compared between groups.

RESULTS
The TO group included 17 older participants, but the NTO group had 10 older participants. Mean step length, velocity and double support time in the TO group did not differ from the NTO group in baseline walking at self-selected speeds. During obstacle crossing, both groups had similar stepping velocity (1.22 ± 0.21 m/s in the TO group versus 1.31 ± 0.16 m/s in the NTO group). However, the TO group had significantly reduced foot-ground height and reduced stride length compared with the NTO group. The TO group also had significantly poorer adapted stride length than the NTO group in response to stepping targets.

DISCUSSION AND CONCLUSION
The novel test could safely challenge walking to identify those with impaired gait adaptability. Walking at preferred speed when there was no challenge did not identify people at risk of falling. Assessing step length/foot-ground height adaptability, which are essential for safe navigation, could identify people who might need to participate in an intervention program.

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5.85

Reliability of Lower Extremity Kinematics in Three-Dimensional Gait Measurements in Children with Cerebral Palsy

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BACKGROUND

Cerebral Palsy is a complex pathology that describes a group of motor disorders[1] with different presentations and functional levels[2]. Three-dimensional gait analysis is used in the assessment of CP children to assist in clinical decision making and assessing outcomes in the rehabilitation process[3]. Due to the CP intra-subject gait variability[4], it's crucial to access the repeated gait measurements to evaluate the response to therapeutic interventions in the rehabilitation process.

AIM

The objective of this study was to determine the intra-subject measurement reliabilities of the kinematic parameters of children with hemiplegic and diplegic type of cerebral palsy.

METHOD

The study group was composed of a convenience sample of 8 CP children able to walk independently (2 hemiplegic, 6 diplegic; 2 female, 6 males; age 87.88±25.56months; height 1.17±0.14m; mass 24.25±8.26kg). Two trials were performed on two different days within period of 7.5±1.4days. Two assessors positioned the reflective marker set based on the CAST protocol[5]. Data was collected with 8 infrared, high-speed cameras working at 200 Hz. Intraclass correlation coefficients considering the two-way mixed model, absolute agreement (ICC[2,k])[6,7] for these trials were calculated for kinematic parameters. The ICC level of clinical significance was considered poor, fair, good, and excellent when ICC<0.40, 0.40<ICC<0.59, 0.60<ICC<0.74, 0.75<ICC<1.00[8].

RESULTS

Intraclass correlation coefficients were calculated for the joint angles peak values in the gait cycle (from heel strike to terminal swing) on both sides. The considered joint angles were in the range of motion of the flexion/extension, abduction/adduction, and rotations, in the pelvis, hip, knee, and ankle. Reliability of kinematics was excellent in the most variables (22 of 48), good (10 of 48), fair (8 of 48) and poor (8 of 48). Overall, joint angles of the right lower limb showed the greatest differences and variability, mainly in the Hip flexion (0.141, 95%CI – 0.000 to 0.842); Knee abduction (0.370, 95%CI–0.000 to 0.879) and adduction (0.332, 95%CI – 0.000 to 0.807); Ankle plantar flexion (0.000, 95%CI – 0.000 to 0.807) and inversion (0.000, 95%CI – 0.000 to 0.755).

DISCUSSION AND CONCLUSION

In this study, there were greater differences in frontal and transverse planes of the right lower limb. The inclusion of two hemiplegic CP children affected on the right lower limb, may have contributed to a larger variability of the assessments due to the irregularity of muscle spasticity that can affect the participants gait patterns and consequently the joint angles. Presented data shows that most of the assessed kinematics measurements can be replicated to a moderate extent.

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5.86

Trip Recovery Responses during Trip-like Perturbation to Non-prosthetic versus Prosthetic Legs in Individuals with Unilateral Transtibial Amputation

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BACKGROUND

Elevated risk of falling in individuals with lower limb amputation remains an issue that threatens this population's mobility and quality of life.[1] Literature has shown that when individuals with transfemoral amputation being tripped on the non-prosthetic and the prosthetic sides, they exhibited distinct recovery strategy and more susceptible to fall when tripped on the prosthetic side.[2] However, the non-prosthetic versus prosthetic side trip recovery mechanism remains unclear in persons with transtibial amputation.

AIM

To explore the trip recovery responses during simulated tripping perturbations delivered to the non-prosthetic leg versus the prosthetic leg in individuals with unilateral transtibial amputation.

METHOD

Individuals with unilateral transtibial amputation and age-, gender- matched individuals without amputation were recruited. All participants walked on a dual belt instrumented treadmill with their preferred walking speeds (PWS) (Bertec Corporation, USA). Trip-like perturbations were delivered via unexpected acceleration of one of the treadmill belts during early stance phase using a previously validated protocol.[3] Perturbations with two levels of severity (i.e. mild/severe accelerations) were applied to non-prosthetic legs (NPL) and prosthetic legs (PL) of amputee participants, and dominant legs of non-amputee controls (NAL) randomly. The recovery responses were quantified by peak trunk flexion angle and peak trunk flexion velocity.[4] Perturbation accelerations and trunk flexion velocity were normalized to PWS.

RESULTS

The 3 amputee participants were 73, 59, and 58 years old (PWS 0.53m/s); their age-matched counterpart were 67, 60, and 59 years old (PWS 1.03m/s). In the events where the participants successfully arrest the falls due to the imposed perturbations, we observed a trend that amputees showed similar peak trunk flexion angle to non-amputees but more exaggerated peak trunk flexion velocity. Moreover, PL trips elicited higher peak trunk flexion velocities than NPL trips, regardless of the perturbation severity.

	Peak Trunk Flexion Angle (°)		Peak Trunk Flexion Velocity (°/sec)	
	Mild	Severe	Mild	Severe
Non-prosthetic (NPL)	20.69 ± 11.69	30.15 ± 13.34	155.98 ± 92.72	183.11 ± 50.86
Prosthetic (PL)	26.97 ± 17.80	30.38 ± 16.23	184.94 ± 83.49	234.12 ± 42.17
Non-amputee (NAL)	21.02 ± 6.00	31.02 ± 11.09	112.46 ± 38.51	190.31 ± 44.37

DISCUSSION AND CONCLUSION

Aligns with findings in individuals with transfemoral amputation, the 3 transtibial amputated participants also showed greater peak trunk flexion when the trip-like perturbations were applied to the PL, comparing to NPL.2 Amputee participants exhibited comparable performance during NPL trips to non-amputees. However, trips to PL elicited greater peak trunk flexion velocities than NPL and NAL. This may indicate that tripping the prosthetic leg of individuals with unilateral transtibial amputation demanded a higher level of trunk control to prevent falling.

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5.87

Normalization Alters the Interpretation of between Limb Differences in Peak Isometric Hip Extension Torque among Lower Limb Prosthesis Users

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BACKGROUND

Normalization of strength measures is recommended to minimize the influence of body dimension variables like mass, height, or body-size. The relationship between strength and body dimensions has however been overlooked when assessing lower limb prosthesis (LLP) users. A recent review of strength deficits in LLP users found only 3 of 12 studies normalized their data, doing so by body mass (1). Our understanding of post-amputation muscle weakness may therefore be confounded by body dimension variables.

AIM

The aim of this study was to evaluate the effect of normalization in order to identify a suitable variable by which to normalize.

METHOD

Laying supine on an isokinetic dynamometer (hip flexed 20°), participants performed 15 maximum voluntary isometric hip extension contractions with residual and intact limbs. Hip extension strength was quantified via peak torque over the first five trials. Correlation coefficients were computed to: i) identify confounding relationships between non-normalized peak torque and body dimension variables (i.e., mass, height, body-size), and ii) evaluate effectiveness of normalization in minimizing the influence of body dimension variables on hip extension strength. Peak torque was normalized by ratio scaling (i.e., peak torque/body dimension variable). To evaluate the impact of normalization on post-amputation muscle weakness, peak torque was compared between limbs with paired t-tests before and after normalization.

RESULTS

Seventeen LLP users (10 transtibial, 12 non-dysvascular, 11 male) completed the study. Indicating a need for normalization, hip extension strength demonstrated a degree of dependency on body dimensions as evidenced by moderate to strong (r=.42-.53) and statistically significant correlations (p<.05) between non-normalized peak torque and height, segment length, and body-size in the intact and residual limbs (Table 1). Body mass and peak torque were not significantly correlated in the intact or residual limbs. Normalizing peak torque by height or segment length did not reduce correlation magnitude (i.e., dependency), but normalizing by body-size (i.e., body mass*segment length) did (Table 1). Prior to normalization, peak hip extension torque was significantly greater in the intact than residual limb (p=.04). After normalization by body-size, there was no significant difference between limbs.

Table 1. Pearson correlation coefficients relating body dimension variables to peak isometric hip extension torque before and after normalization

	Peak isometric hip extension torque			
	Intact limb		Residual limb	
Body dimension variables	Non-normalized r-value (*p-value*)	Normalized r-value (*p-value*)	Non-normalized r-value (p-*value*)	Normalized r-value (*p-value*)
Body mass	0.337(*.093*)	-0.093 (*.722*)	0.284 (*.135*)	-0.145 (*.580*)
Height	0.528 (*.015*)	0.496 (*.043*)	0.483 (*.025*)	0.448 (*.072*)
Segment length	0.524 (*.015*)	0.492 (*.045*)	0.372 (*.071*)	0.115 (*.662*)
Body size[a]	0.422 (*.046*)	-0.046 (*.862*)	0.442 (*.038*)	-0.041 (.875)

a: Body size=body mass*limb length; limb length was defined as thigh length for all intact limbs and the residual limb of transtibial prosthesis users. The residual limb length of transfemoral prosthesis users was measured as the distance from the ischium to the distal end.

DISCUSSION AND CONCLUSION

Our results suggest that: i) peak hip extension torque in LLP users should be normalized by body-size (using limb length rather than height), not body mass, and ii) failure to normalize strength measures in LLP users may confound results, alter their interpretation, and influence treatments and questions clinicians and researchers pursue, respectively. Further research with a larger sample, additional strength measures, alternative normalization techniques, and other muscle groups is required.

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