abc10
10th australasian biomechanics conference
December 4th - 6th 2016 Melbourne, Australia

‘MECHANOBIOLOGY ACROSS THE SCALES’
Showcasing the latest in Biomechanics Research

BOOK OF ABSTRACTS
DAY 1

ANZSB
anzsb.asn.au
THE UNIVERSITY OF
MELBOURNE
## PROGRAM & ABSTRACTS

### DAY 1  
**Sunday 4th December 2016**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00am</td>
<td><strong>REGISTRATION</strong> at the Woodward Conference Centre</td>
</tr>
</tbody>
</table>
| 9:00am - 10:30am | **WORKSHOP PART 1: FROM MODELS TO DECISIONS:**  
Translating biomechanics research to the clinical setting  
Organisers: Morgan Sangeux (Murdoch Childrens Research Institute), Anna Murphy (Monash Health) |
| 9:00am    | **INTRODUCTION & OBJECTIVES: BIOMECHANICS DRIVEN CLINICAL DECISIONS**  
*Morgan Sangeux, Murdoch Childrens Research Institute* |
| 9:20am    | BIOMECHANICS ANALYSIS CAN ASSIST RETURN TO SPORT DECISIONS IN ELITE ATHLETES  
*Jodie McClelland, La Trobe University* |
| 9:32am    | KINEMATICS AND KINETICS DURING STAIR ASCENT IN INDIVIDUALS WITH SYMPTOMATIC GLUTEAL TENDINOPATHY  
*Kim Allison, University of Melbourne* |
| 9:44am    | CHARACTERISATION OF LOWER LEG MUSCLE MORPHOLOGY AND FUNCTION: IMPLICATIONS FOR MEDIAL TIBIAL STRESS SYNDROME - WORK IN PROGRESS  
*Josh Mattock, University of Wollongong* |
| 9:56am    | DOES FRONTAL PLANE KNEE MOTION INFLUENCE OSTEOARTHRITIS TREATMENT OUTCOMES? EXPLORATORY ANALYSES FROM THE INTENSIVE DIET AND EXERCISE FOR ARTHRITIS (IDEA) TRIAL  
*Michelle Hall, University of Melbourne* |
| 10:08am   | Panel discussion on biomechanics informed clinical decisions          |
| 10:30am - 11:00am | Morning Tea                                                               |
INTRODUCTION
The decision for return to sport following injury in elite athletes is complex and multifactorial. Often, there are competing interests that weigh on the decision for return to sport, and any decision requires consideration of the potentially significant implications for the long-term health of the player, particularly the risk of further injury. There are often underlying factors that contribute to the risk of injury in athletes. Most elite athletes undergo routine clinical testing that can identify traits that are associated with greater risk of injury. These tests commonly include assessment of strength, flexibility, agility, power, and cardiovascular fitness. The assessment of biomechanics in sport-specific tasks can facilitate greater understanding of the movement strategies adopted by athletes that may contribute to injury, and in the case of athletes following anterior cruciate ligament reconstruction, can help to predict the risk of further injury and provide feedback about the functional outcome of the surgery.

METHODS
We have provided an ad hoc clinical service to several elite level Australian Football League and A-League clubs to assess biomechanics during sports-specific tasks. More than 20 of these athletes had recently undergone anterior cruciate ligament reconstruction surgery. The biomechanics of these athletes were assessed during high-risk landing tasks at a time when return to sport was being considered. These biomechanics were compared to a database of 80 patients with anterior cruciate ligament reconstruction who had successfully returned to lower-level sports following surgery. The biomechanics of two athletes with recurrent hamstring injuries, and one athlete with a non-resolving foot injury have also been described during sports-specific tasks.

RESULTS AND DISCUSSION
The biomechanics assessments have provided valuable information that was considered in the return to sport decision-making process for these athletes. In some cases, return to sport was reconsidered in light of the biomechanics information, as in the following case example. In this case, the athlete demonstrated a peak knee flexion moment on the injured limb during running that was considerably lower than the non-injured limb and also lower than athletes who had returned to similar sports. The athlete’s return to sport was delayed and the rehabilitation goals were modified, and on testing at time 2, demonstrated much more symmetrical and normal knee flexion moment.

CONCLUSIONS
Younger athletes with anterior cruciate ligament reconstruction adopt single limb landing strategies that are different from normal. Greater pelvis anterior tilt and hip flexion at initial contact support recent evidence that aberrant movement strategies in patients with anterior cruciate ligament reconstruction manifest at more proximal joints to the knee. The shorter time to stabilisation may reflect adoption of an abnormal bracing strategy during landing.

ACKNOWLEDGEMENTS
The authors would like to acknowledge the contributions of Dr Clare Ardern and Dr Joanne Wittwer in assisting with data collection.
INTRODUCTION
Gluteal tendinopathy (GT) is a debilitating cause of lateral hip pain most prevalent in middle-age women [1]. Although pain and disability during stair climbing are typical features of GT [1] no studies have evaluated biomechanics during stair ascent in GT.

METHODS
Three-dimensional gait analysis of a reciprocal step-up task (2 steps) was conducted on 35 asymptomatic controls (ASC) and 35 individuals with unilateral GT. Using a Vicon MX system, kinematic and kinetic data were calculated from skin marker triads and ground reaction forces from the first step, using inverse dynamics. Stance phase on the first step (symptomatic limb) was analysed during: (1) vertical thrust (0-50% stance) and (2) forward continuance (50-100% stance)[2]. Normalized (Nm/BW.Ht%) peak external hip adduction (HADM), flexion, internal rotation moments and positive impulses were averaged over 3 trials, for 0-50 and 50-100% stance. Maximum hip adduction, flexion, internal rotation angles, contralateral pelvic drop, lateral pelvic translation and lateral trunk lean were quantified at: (1) foot contact (FC); (2) between FC and reciprocal toe off (RTO); and (3) RTO - 100% stance. ANOVA compared data between groups, and secondary analyses performed on the basis that multiple step-up strategies are possible [2].

RESULTS AND DISCUSSION
The GT and ASC groups were comparable in age (54±8 vs 53±9 years) and sex (females=26). The GT group had a greater BMI (GT=26±4 kg/m², ASC=24±3 kg/m², P<0.05). Median (IQR) duration of GT symptoms was 18±28 months, and pain experienced over the past week was 4±2 inter-ASIS% ˚, P<0.01). A greater external HADM in those with GT during stair ascent (established by two analyses) implies greater requirement for internal abductor moment generation by the hip abductor muscles, including the gluteus minimus and medius implicated in GT. This finding is consistent with findings in walking in this group [3], however a larger HADM may have greater clinical relevance for overload of the gluteal tendons and the development and/or perpetuation of GT.

CONCLUSIONS
Individuals with GT exhibit greater HADM and differences in frontal plane pelvic / trunk kinematics during stair ascent than ASCs. Longitudinal research is needed to evaluate whether these movement patterns contribute to the development of GT.

REFERENCES
CHARACTERISATION OF LOWER LEG MUSCLE MORPHOLOGY AND FUNCTION: IMPLICATIONS FOR MEDIAL TIBIAL STRESS SYNDROME – WORK IN PROGRESS

Joshua Mattock¹, Karen Mickle², and Julie R. Steele¹

¹Biomechanics Research Laboratory, University of Wollongong, NSW, Australia
²Institute of Sport, Exercise & Active Living, College of Sport and Exercise Science, Victoria University, VIC, Australia
Email: jpmm565@uowmail.edu.au

INTRODUCTION

Medial tibial stress syndrome (MTSS) is an overuse injury with a prevalence rate between 4-35% that predominately affects military personal and distance runners [1]. Imaging studies suggest bone stress is the most likely cause of MTSS as it is hypothesised that bony adaptations of the tibia are unable to keep pace with repetitive loading of the lower limb [1]. To date, however, research has failed to find a management strategy for MTSS that is more effective than prolonged rest, necessitating the need for further research to elucidate possible causative factors of the injury [2].

Several risk factors have been reported to contribute to the development of MTSS. These include female gender, previous history of MTSS, fewer years running experience, increased navicular drop, increased external hip rotation, a body mass index greater than 21 and lean lower leg girth [3]. Lean lower leg girth, however, is reported as a risk factor based solely upon measurements of overall lower leg circumference at its largest girth and skin fold measures [4, 5]. As a result there is a lack of evidence to describe the composition of lower leg musculature and how that contributes to changes in overall lower leg girth and the development of MTSS. Therefore, the purpose of this study is to identify differences in lower leg muscle morphology and function of individuals with and without MTSS symptoms, and to ascertain which factors contribute to the development of MTSS.

METHODS

Twenty-five individuals with a history of MTSS symptoms and 160 asymptomatic individuals will be recruited for this study. All participants will be distance runners, aged 18 years and older, who run an average of 30 km per week or are training for a long distance running event. After assessing his or her height and weight, each participant’s bone quality will be assessed using a Mini-Omni ultrasound bone sonometer (BeamMed Ltd, Israel). Muscle morphology of the tibialis anterior, peroneals, flexor digitorum longus, flexor hallucis longus, medial gastrocnemius, lateral gastrocnemius and soleus will then be assessed using a B-mode ultrasound (SonoSite, Inc., Bothell, WA, USA). Lower leg function will be assessed using a B-mode ultrasound (SonoSite, Inc., Bothell, WA, USA). Kinematic data characterising running technique will be collected using an Optotruk Certus motion capture system (100 Hz) (Northern Digital Inc., Ontario, Canada) and plantar pressure distributions during running will be quantified using Pedar-X insoles (100 Hz) (Novel gmbh, Munich, Germany). Finally, each participant’s lower limb muscular endurance will be assessed using a maximal single leg heel raise protocol.

Once baseline data are collected for both symptomatic and asymptomatic individuals, the asymptomatic participants will be tracked longitudinally to assess any runners who develop MTSS over the course of the next 12 months. Descriptive statistics for the two groups will be calculated at baseline. If the data are normally distributed, independent samples t-tests will be conducted to identify any between group differences (p < 0.05). A regression analysis will then be used to determine which variables are likely to predict the development of MTSS, for the 160 participants who were followed longitudinally for 12 months.

RESULTS AND DISCUSSION

The results of this study will allow us to identify characteristics of individuals who develop MTSS symptoms and, in turn, identify modifiable risk factors that can be targeted in an attempt to prevent individuals developing this syndrome.

ACKNOWLEDGEMENTS

Funding for this study has been provided by the Australian Podiatry Education and Research Foundation.

REFERENCES

Does frontal plane knee motion influence osteoarthritis treatment outcomes? Exploratory analyses from the Intensive Diet and Exercise for Arthritis (IDEA) trial

Michelle Hall1, Kim L Bennell1, Daniel P Beavers2, Tim V Wrigley3, Paul DeVita3 and Stephen P. Messier4

1Centre for Health, Exercise and Sports Medicine, University of Melbourne, VIC, Australia
2Division of Public Health Sciences, Wake Forest School of Medicine, Winston-Salem, NC, USA
3Department of Kinesiology, College of Health and Human Performance, East Carolina University, Greenville, NC, USA
4Department of Health and Exercise Science, Wake Forest University, Winston-Salem, NC, USA

halm@unimelb.edu.au

INTRODUCTION

Although diet and/or exercise interventions provide pain relief and improvement in physical function for patients with knee osteoarthritis (OA) [1], tailoring interventions to patient-specific characteristics may enhance these outcomes. Patient-specific characteristics related to knee kinematics in the frontal knee plane during walking may influence treatment outcomes. Preliminary evidence suggests that frontal plane knee motion moderates pain following a 12-week exercise intervention in patients with knee OA [2]. A recent RCT comparing neuromuscular and quadriceps strengthening exercise found similar improvements in pain [3]. However, in exploratory sub-group analyses those with a visually-observed varus thrust obtained greater pain relief with neuromuscular exercise than with quadriceps strengthening [2] despite similar knee strength gains [3]. Varus thrust did not mediate physical function [2]. Peak varus knee angular velocity is related to a varus thrust assessed subjectively [4], and thus is of clinical relevance given that frontal plane motion can be assessed clinically by simple visual assessment. The aim of this study was to determine if baseline peak varus knee angular velocity was a predictor of change in pain and physical function subsequent to 18 month interventions of exercise and/or diet or exercise alone.

METHODS

387 participants (65±6yrs; 33.6±3.7 kg/m2; male 24%) underwent 3D gait analysis at baseline. Frontal plane knee joint motion during walking was measured as peak varus angular velocity (i.e., varus thrust). Participants completed the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) questionnaire at baseline and follow-up. Linear regression was used to determine the association between baseline peak varus angular velocity (independent variable) and 18-month change in self-reported pain and function (dependent variables) for each intervention (exercise, diet, exercise + diet).

RESULTS AND DISCUSSION

Pain relief was significantly associated with higher peak varus angular velocity (our measure of varus thrust) in the diet-only and exercise-only groups (Table 1). It is unclear why there was no significant association between change in pain and peak varus angular velocity in the combined diet and exercise group (Table 1). Improved physical function was associated with a higher peak varus angular velocity in the exercise-only group. No other significant associations were observed for physical function (Table 1). Thus, we interpret these findings with caution, as a similar observation was not found in the combined diet and exercise intervention group despite similar magnitudes of pain relief and loss in body weight.

CONCLUSIONS

Despite some statistically significant associations, strength of the associations were weak, indicating that peak varus angular velocity has questionable predictive capacity on outcomes following diet and exercise interventions in overweight and obese knee OA patients.

REFERENCES


Table 1: Association between peak varus velocity (deg/s) (i.e., varus thrust) and 18-mth change in WOMAC pain and function.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Group</th>
<th>Unadjusted analysis</th>
<th>p-values</th>
<th>Adjusted analysis</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>Exercise Only</td>
<td>-0.03 (-0.07, 0.00)</td>
<td>0.052</td>
<td>-0.04 (-0.07, -0.01)</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>Diet Only</td>
<td>-0.01 (-0.04, 0.02)</td>
<td>0.358</td>
<td>-0.03 (-0.06, -0.00)</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>Exercise &amp; Diet Only</td>
<td>0.02 (-0.01, 0.06)</td>
<td>0.192</td>
<td>0.02 (-0.01, 0.05)</td>
<td>0.214</td>
</tr>
<tr>
<td>Function</td>
<td>Exercise Only</td>
<td>-0.07 (-0.17, 0.03)</td>
<td>0.169</td>
<td>-0.11 (-0.20, -0.01)</td>
<td>0.030</td>
</tr>
<tr>
<td></td>
<td>Diet Only</td>
<td>-0.05 (-0.13, 0.04)</td>
<td>0.250</td>
<td>-0.08 (-0.16, 0.01)</td>
<td>0.088</td>
</tr>
<tr>
<td></td>
<td>Exercise &amp; Diet Only</td>
<td>0.08 (-0.02, 0.18)</td>
<td>0.126</td>
<td>0.10 (-0.00, 0.20)</td>
<td>0.051</td>
</tr>
</tbody>
</table>

Adjusted for sex, baseline BMI, baseline value of pain or function as appropriate, age, alignment category, radiographic disease severity
<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:00am - 12:30pm</td>
<td><strong>WORKSHOP PART 2: FROM MODELS TO DECISIONS:</strong> Translating biomechanics research to the clinical setting</td>
</tr>
<tr>
<td></td>
<td>Organisers: Morgan Sangeux (Murdoch Childrens Research Institute), Anna Murphy (Monash Health)</td>
</tr>
<tr>
<td>11:00am</td>
<td><strong>OBJECTIVES:</strong> DATA-INFORMED CLINICAL DECISIONS AND CLINICAL MEASUREMENTS</td>
</tr>
<tr>
<td>11:15am</td>
<td><strong>DATA-DRIVEN MODEL TO IMPROVE DECISION-MAKING IN AFO PRESCRIPTION AND DESIGN FOR CHILDREN WITH CEREBRAL PALSY: A PRELIMINARY STUDY</strong></td>
</tr>
<tr>
<td></td>
<td>Julie Choisne, University of Auckland</td>
</tr>
<tr>
<td>11:27am</td>
<td><strong>HOW CAN THE GAIT PATTERNS OF CHILDREN WITH CHARCOT-MARIE-TOOTH DISEASE DETERMINE THE DESIGN REQUIREMENTS OF 3D PRINTED ANKLE FOOT ORTHOSES</strong></td>
</tr>
<tr>
<td></td>
<td>Elizabeth Wojciechowski, Sydney Children’s Hospitals Network</td>
</tr>
<tr>
<td>11:39am</td>
<td>Panel discussion on data-driven clinical decisions</td>
</tr>
<tr>
<td>11:51am</td>
<td><strong>MEASURING PELVIC TILT IN FEMOROACETABULAR IMPINGEMENT USING AN ACCELEROMETER</strong></td>
</tr>
<tr>
<td></td>
<td>Joe Lynch, Australian National University</td>
</tr>
<tr>
<td>12:03pm</td>
<td><strong>TESTING THE TEKSCAN 9833E PRESSURE SENSOR SYSTEM FOR MEASUREMENT OF PRESSURE DISTRIBUTION DELIVERED BY LYMPHOEDEMA COMPRESSION SLEEVES</strong></td>
</tr>
<tr>
<td></td>
<td>Daniel Hageman, University of New South Wales</td>
</tr>
<tr>
<td>12:15pm</td>
<td><strong>CUSTOMISING OPENSIM MODELS USING THE MUSCULOSKELETAL ATLAS PROJECT</strong></td>
</tr>
<tr>
<td></td>
<td>Thor Besier, University of Auckland</td>
</tr>
<tr>
<td>12:30pm - 1:30pm</td>
<td>Lunch</td>
</tr>
</tbody>
</table>
DATA-DRIVEN MODEL TO IMPROVE DECISION-MAKING IN AFO PRESCRIPTION AND DESIGN FOR CHILDREN WITH CEREBRAL PALSY: A PRELIMINARY STUDY

Julie Choisne1, Geoffrey Handsfield1, Nada Signal2, Denise Taylor7, Nichola Wilson3, Susan Stott3 and Thor Besier1

1 Auckland Bioengineering Institute, University of Auckland, Auckland, New Zealand
2 Health and Rehabilitation Research Institute, Auckland University of Technology, Auckland, New Zealand
3 Starship Children’s Hospital, Auckland District Health Board, Auckland, New Zealand
Corresponding author's email: jcho911@aucklanduni.ac.nz

INTRODUCTION
Ankle-foot orthoses (AFOs) are frequently prescribed to help children with cerebral palsy (CP) maintain independent mobility with the aim of providing a stable base of support, improving gait mechanics and reducing metabolic cost. However, the clinical outcomes from AFOs are variable due to differences in design, fitting, and patient pathology. Currently, prescription of AFOs relies on clinical assessments and observation of walking pattern. Consequently, the prescription and design of AFOs is subjective, depending heavily on the expertise and knowledge of the orthotist or prescribing clinician and requires a process of trial and error.

3D gait analysis (3DGA) is state-of-the-art technique in the diagnosis of gait pathology in CP and is used to inform orthopaedic surgery, prescription of orthoses, and ongoing rehabilitation. To date, interpretation of 3DGA data is subjective and it is not clear if any combination of clinical assessment and 3DGA parameters can quantitatively inform the prescription and design of AFOs. Data-driven modelling approaches have the potential to reveal non-intuitive relationships between 3DGA, clinical measurements, and AFO design [1]. Previous data-driven modelling applied to CP determined traits associated with good surgical outcomes from large and complex data, providing support for the approach [2].

The aim of the study is to develop a bioengineering tool to inform decision-making and improve the process of prescription and design of AFOs for children with CP.

METHODS
The study consists of two steps: 1) Build a model based on retrospective data from >100 children with cerebral palsy that underwent 3DGA barefoot and with an existing orthosis prescription, 2) Evaluate the potential benefit of the model in prescribing AFOs by applying the model to a representative sample of patients that are not included in the training set.

Modelling: Support Vector Machine (SVM) is a powerful machine learning classification technique that we will use to classify gait patterns [3] and inform on the best AFO for each ‘gait pattern’. The model will use a training dataset containing the clinical and barefoot 3DGA parameters as inputs and create classes to classify each individual depending on their gait pattern. Then, each new patient will be assigned a class according to their clinical similarities with the training dataset. Based on the Movement Analysis Profile (MAP) [4] scores within the assigned class, the model will suggest the type of AFO that will most likely improve their individual gait variable scores (GVS) [4] (Figure 1). The Gait Profile Score (GPS) will also be used to assess the overall gait improvement between barefoot and AFO. We chose to concentrate on the GVS and GPS variables for the model outcomes because these parameters are clinically meaningful in terms of kinematic measures.

Benefit estimation: A representative sample of children with CP will be used to estimate the clinical benefit of the model. All limbs from the benefit sample will be processed by the model. The benefit will be calculated by comparing each of the nine GVS from the existing orthosis prescription to the predicted GVS from the orthosis designs recommended by the model.

CONCLUSIONS
Preliminary findings will be presented at the conference in December. This model will be integrated into a novel workflow to improve the process of prescription and design of AFOs for children with CP.

ACKNOWLEDGEMENTS
We would like to thanks the MedTech CoRE for funding this project through the Seed Project Funding.

REFERENCES

Figure 1: Model description using clinical parameter and 3DGA features as input and individual GVS as outcome measure.
HOW CAN THE GAIT PATTERNS OF CHILDREN WITH CHARCOT-MARIE-TOOTH DISEASE DETERMINE THE DESIGN REQUIREMENTS OF 3D PRINTED ANKLE FOOT ORTHOSES

Elizabeth Wojciechowski¹, Sean Hogan², David Little², Manoj Menzes² and Joshua Burns¹,³
¹Paediatric Gait Analysis Service of New South Wales, Sydney Children’s Hospital Network, Australia
²The Children’s Hospital at Westmead, New South Wales, Australia
³Faculty of Health Sciences, The University of Sydney, New South Wales, Australia

INTRODUCTION
The most common gait abnormalities reported in children with Charcot-Marie-Tooth disease (CMT) include foot-drop, reduced ankle push-off and increase knee and hip flexion or ‘steggage’ gait for swing clearance. However, several other deviations at the ankle and related compensatory mechanisms have been reported [1]. This suggests that children with CMT do not fit a single gait profile and may require more personalised orthotic devices.

Ankle-foot orthoses (AFOs) are commonly prescribed orthoses for children with CMT. AFOs are usually handmade by plaster cast followed by thermoplastic moulding. This traditional approach provides limited design options, can be costly, with long outpatient wait times. 3D printing, also known as additive manufacturing, has the potential to transform the way AFOs are prescribe, designed and manufactured.

The purpose of this study was to identify 3D gait patterns of children with CMT based on severity of functional weakness using the CMT Pediatric Scale (CMTPeds) and to determine how these patterns could influence the design of 3D printed AFOs.

METHODS
Peak joint angles, moments and powers during gait were captured with an 8-camera Vicon Nexus motion capture system using the lower body Plug-in-Gait model in 60 children with CMT (34 male, 26 female; mean age 11±3.1yrs, mean height 147±16.8cm, mean weight 44±17.4kg, of various CMT types (47 CMT1A, 4 CMTX, 2 CMT1F, 2 CMT4C, 1 CMT2A and 4 genetically unclassified) and compared to 50 healthy norms (15 male, 35 female; mean age 9.8±3.8yrs, mean height 140±19.6cm, mean weight 39±19.0kg). Data were subdivided into three groups denoting increasing severity of dorsiflexion and plantarflexion weakness: no difficulty heel or toe walking (CMTND), difficulty heel walking (CMTDH), difficulty toe and heel walking (CMTDT).

RESULTS AND DISCUSSION
Three distinct gait patterns at the ankle were identified. The CMTND group showed a near-normal gait pattern. The only significant differences noted in the ankle kinematics were reduced peak dorsiflexion in stance (p<0.05) (Figure 1a). In addition to reduced dorsiflexion in stance the CMTDH group demonstrated significantly reduced ankle dorsiflexion in swing (drop-foot) and a reduced ankle dorsiflexor moment in loading response indicating a lack of first rocker (p<0.001) (Figure 1b). In contrast to the first two groups the CMTDT group presented with significantly delayed and increased peak ankle dorsiflexion during stance and reduced ankle plantarflexion and power at push-off (p<0.05) (Figure 1c). They also had a significantly reduced minimum knee extensor moment in stance compared to healthy norms (p<0.05).

To improve gait patterns of children with CMT with orthotic devices the design requirements of the three groups are very different. The CMTND group requires a device to prevent drop-foot in swing and provide a first rocker during loading response whilst allowing ankle plantar flexion and power at push-off. In contrast, the CMTDH group requires a device to limit the amount of peak dorsiflexion, assist movement of the ground reaction force in front of the knee during stance and provide ankle power at push-off.

CONCLUSIONS
Classifying 3D gait patterns on based on severity of functional weakness in children with CMT identified three distinct gait patterns. Current AFOs prescribed for children with CMT do not meet all the requirements identified due to the limitations of traditional manufacturing methods. Each group would require specific orthotic designs that could be manufactured using 3D printing methods.

REFERENCES

Figure 1: Ankle dorsiflexion angle of the healthy norms (light grey area, mean ±1 SD) and three CMT groups: a) CMTND, b) CMTDH; c) CMTDT.
INTRODUCTION
Femoroacetabular impingement (FAI) is considered a common mechanism leading to early cartilage and labral damage in the hip joint [1]. FAI encompasses structural deformities on the femoral neck (cam lesions), acetabular rim (pincer lesions) or a mixed pattern of these lesions. While arthroscopic surgery is increasingly being employed to resect impinging bone, it may be possible to reduce the incidence and severity of impingement by optimising non-operative measures, such as by altering pelvic tilt to avoid impingement.

Pelvic tilt has a significant effect on the acetabulum’s coverage of the femoral head [2]. Anterior tilt of the pelvis is likely to exacerbate anterior overcoverage and subsequent impingement, while posterior tilt is likely to reduce it.

Currently, little is known regarding how pelvic tilt changes during daily activities, such as lying, standing and sitting in FAI subjects. Standard methods to measure pelvic tilt include using lateral xrays, which have the disadvantage of significant radiation exposure to a young cohort, or using camera-based systems with skin markers, which have the disadvantage of skin artefact.

In this study, the feasibility of using a skin-mounted accelerometer to measure pelvic tilt was investigated and implemented in an FAI cohort.

METHODS
18 subjects diagnosed with FAI on clinical and radiographic criteria, who were awaiting arthroscopic surgery, were recruited, along with 18 age and sex matched normal subjects with no known hip pathology. Each subject had a triaxial accelerometer/ gyroscope/compass (MPU-9125, Invensence) mounted on the skin between the posterior superior iliac spines, and the signal was transmitted via Bluetooth to a PC. Inclination of the accelerometer in the sagittal plane was measured during standing, lying, sitting on the edge of a bed and sitting on a chair. The relationship between the inclination of the accelerometer and the anterior pelvic plane was calibrated using a custom rig with three plastic limbs defining the anterior pelvic plane: each ASIS and the pubic symphysis. An inclinometer (Dualer IQ digital, JTech Biomedical) attached to the rig enabled the tilt of the accelerometer to be referenced to the anterior pelvic plane.

The accuracy of this method was validated in 10 subjects against CT scans. With each subject lying down on the CT gantry, pelvic tilt was measured using the accelerometer, and compared with pelvic tilt measured directly from bony landmarks (ASIS and pubic symphysis) identified on CT.

RESULTS AND DISCUSSION
Mean differences between the pelvic tilt measured using the accelerometer and CT was -4.8° (SD 5.3°). The main reason for this difference was due to greater thickness in soft tissue covering the pubic symphysis compared to the ASIS.

Early results for the first 20 recruited FAI and normal subjects revealed mean pelvic tilt were 4.0° (SD 4.5°) and 4.1° (SD 9.6°) while lying and standing, respectively, in the FAI group, and -5.6° (SD 2.8°) and -1.8° (SD 0.6°) in the normal group. Mean pelvic tilt while sitting on a hard backed chair and on the side of a bed were -17.4° (SD 16°) and -12.8° (SD 13.9°), respectively, in the FAI group and -36.8 (SD 1.5°) and -24.1° (SD 2.5°) in the normal group. This trend, while not statistically significant due to small normal cohort, may suggest that FAI subjects are more anteriorly tilted when sitting on a chair, which increases the chance of impingement between the anterior acetabular rim and femoral neck.

CONCLUSIONS
Measuring pelvic tilt without irradiating young patients is desirable, although the CT validation of the proposed method indicated a systematic error of almost 5 degrees compared with direct CT measurements. This study only validated the method with subjects in a supine position, and made the assumption that the relationship between the skin mounted accelerometer and underlying bone remained constant as the pelvis tilted when sitting, which requires further investigation. Early clinical results suggest a trend towards increased anterior tilt in FAI subjects when sitting, which may exacerbate impingement.

REFERENCES
INTRODUCTION
Up to 20% of breast cancer patients will be diagnosed with lateral lymphedema subsequent to axillary lymph node resection for prevention of metastasis. Lymphedema presents itself as a build-up of lymphatic fluid and swelling of lateral tissues, which can result in tissue hardening, loss of function, and psychosocial consequences over time [1].

Currently, there is no cure for lymphedema. A range of empirical treatments are used to prevent and/or mitigate the symptoms of lymphedema, from compression sleeves to lymph drainage massage. The unknown etiology of lymphedema combined with lack of efficacy testing and protocols for side-by-side comparison of treatment modalities confounds the development of ‘best standards’ for lymphedema treatment. As a first step toward testing efficacy of pressure application via compression sleeves for management of lymphedema, this study aims to quantitatively measure the pressure distribution delivered by compression sleeves.

METHODS
Our approach was to implement a new pressure sensing technology that utilises sensor electrodes within a flexible polyester sheet (Tekscan Inc.) to measure pressure gradients between the arm and compression sleeve. First, we tested the efficacy of the sensor itself within target pressure ranges. A 2-point calibration was implemented on the Tekscan 9833E sensor at a range of 10—55 mmHg, as this is the standard pressure range for all classes of lymphedema compression sleeves. A set area (45.39 cm²) of delivered force was applied to the centre of the sensor for each specified pressure measurement. A restricted edit mode (Figure 1) was used to exclude effects of residual pressure readings. A gage linearity and bias study, as well as a gage repeatability and reproducibility study was conducted on the sensor to study its efficacy within the specified pressure ranges.

RESULTS AND DISCUSSION
The gauge linearity and bias study (Figure 2) showed a negative trend in pressure measurement bias with increasing applied reference pressures (p<0.05); i.e., as the reference value for applied force/pressure increased, the measurements detected by the sensor would be increasingly less than the theoretical pressure measurement predicted. The inconsistency for each individual reference pressure was also apparent for 9 out of 10 of the reference values (p<0.05).

Further, 13.5% of the variation observed could be attributed to lack of repeatability, i.e. the capacity for a single user to attain consistent results following repeated experimentation. This degree of variation precludes accurate characterisation of pressure gradients engendered via compression sleeves.

CONCLUSIONS
Pressure measurements made with the Tekscan 9833E sensor showed high variability within ranges relevant to commercially available lymphedema compression sleeves. Not only were the biases for individual measurements shown to be inaccurate, but repeatability of measurement was also inconsistent. These limitations of the Tekscan sensor studied may point to shortcomings intrinsic to using a flexible (non rigid) sensor system for measurement of pressure distributions, which will likely be exacerbated when making measurements on soft surfaces such as lymphedematous arms. Further studies are needed to determine whether other non-distensible sensors may offer advantages for spatial characterisation of pressures applied by lymphedema compression sleeves.

REFERENCES
CUSTOMISING OPENSIM MODELS USING THE MUSCULOSKELETAL ATLAS PROJECT

Thor Besier¹,², Geoffrey Handsfield¹, Thorben Pauli¹, Alex Carleton³, Mark Taylor³ and Ju Zhang¹

¹Auckland Bioengineering Institute, University of Auckland, Auckland, New Zealand
²Department of Engineering Science, University of Auckland, Auckland, New Zealand
³School of Computer Science, Flinders University, Adelaide, Australia

Corresponding author’s email: t.besier@auckland.ac.nz

INTRODUCTION

The clinical impact of musculoskeletal modelling is currently limited, due to the difficulty in generating subject-specific parameters, such as muscle-tendon properties and anatomical geometry [1]. Accurate representation of bone geometry is critical for predicting muscle and joint contact forces, as it influences the muscles’ length, moment arm, and line of action. Customising musculoskeletal models from medical imaging data is time-consuming and not feasible for routine clinical use. It is more common to use simple length scaling of a template model to match a set of anatomical landmarks (i.e. retroreflective markers placed on body segments) and thus, generate a ‘patient-specific’ model. However, linear, isotropic scaling does not capture variation in bone shape and the scaling process can result in bone dimensions that are non-physiological.

Here we illustrate the use of an articulated statistical shape model to customise the lower limb bones, muscles, and joints of an OpenSim musculoskeletal model. The method is developed within the Musculoskeletal Atlas Project (MAP), a Python-based open-source framework.

METHODS

A combined statistical shape model of the pelvis, femur, patella, tibia, and fibula was created from a training set of 26 left lower limb bones manually segmented CT images. Muscle and ligament attachments were identified from a SOMSO model (www.somso.de, Sonneberg, Germany) and embedded onto the parametric bone meshes (Figure 1a). Anatomical landmarks were also embedded in each bone’s reference mesh to generate consistent anatomical coordinate frames (Figure 1b).

Customisation was performed via an optimisation procedure that adjusted the principal components of the shape model (n=5), along with translation of the pelvis (3DOF) and rotational degrees of freedom of the hip (3DOF) and knee (2DOF) [2]. The hip joint centre was constrained to fit within the acetabulum of the pelvis and the knee joint axis was altered to ensure contact between the femur and tibia throughout knee flexion. Muscle volumes were scaled by subject height*mass using the regression provided by Handsfield et al. [3]. Tendon slack lengths were then optimised to ensure that muscle fibres were on the plateau of the force-length relationship.

We tested the ability of the model-based shape estimation to predict lower limb geometry using only 7 motion capture markers. A leave-one-out analysis was used to determine the accuracy of the predicted bone geometry compared to segmented models.

RESULTS AND DISCUSSION

Shape model scaling of lower limb geometry using 7 markers was accurate to <5mm RMS error. Compared to linear isotropic scaling, our method reduced surface error estimation (p<0.001) and provided a feasible set of muscle-tendon parameters that were consistent with the scaled bone geometry.

CONCLUSIONS

We have presented an articulated shape model to customise a lower limb OpenSim musculoskeletal model. The method has been implemented in an open-source software framework, The Musculoskeletal Atlas Project, which can be easily shared and provides users with access to OpenSim’s Python API.

ACKNOWLEDGEMENTS

We would like to thank the US Food and Drug Administration (HHSF22320 1310119C) and the Australian Research Council (LP130100122) for their financial support. We would also like to thank the Victorian Institute of Forensic Medicine (VIFM) for providing the CT images to generate the statistical shape models.

REFERENCES


Figure 1: Parametric mesh of femur (a) illustrating regions of muscle attachment sites and (b) articulated lower limb model. MAP Client interface showing scaling of model to match motion capture markers.
<table>
<thead>
<tr>
<th>Time</th>
<th>Session/Activity</th>
</tr>
</thead>
</table>
| 1:30pm - 2:00pm | **OPENING CEREMONY** at the Woodward Conference Centre  
Moderated by Dr. Tam Nguyen, St Vincent’s Hospital  
Hon. Frank McGuire, Parliamentary Secretary for Medical Research;  
A/Prof. Peter Pivonka, ABC10 Chair & Dr. Elizabeth Clarke, ANZSB President |
| 2:00pm - 4:00pm | **Session 1 · TISSUE ENGINEERING**  
Chairs: Peter Pivonka (University of Melbourne), Peter Lee (University of Melbourne) |
| 2:30pm        | **INVITED SPEAKER**  
EXPERIMENTAL AND NUMERICAL INVESTIGATION OF STRAIN-RATE DEPENDENT MECHANICAL PROPERTIES OF SINGLE LIVING CELLS  
YuanTong Gu, Queensland University of Technology |
| 2:45pm        | **INVITED SPEAKER**  
OPTIMIZED SELECTION OF 3D CERAMIC SCAFFOLDS FOR LARGE SEGMENTAL BONE DEFECTS BASED ON MECHANICAL AND FLUID DYNAMICAL CHARACTERIZATION - APPLICATION TO BAGHDADITE SCAFFOLDS  
Romane Blanchard, University of Melbourne |
| 3:00pm        | **MECHANICAL PROPERTIES OF LATTICE STRUCTURES FOR IMPLANT APPLICATIONS MANUFACTURED BY SELECTIVE LASER MELTING**  
Martin Leary, RMIT University |
| 3:15pm        | **TAILORING THE MECHANICAL PROPERTIES OF HYDROGELS FOR CARTILAGE TISSUE ENGINEERING**  
Cathal O’Connell, University of Wollongong |
| 3:30pm        | **DAMAGE AND FRACTURE EVALUATION OF BIOLOGICAL SOFT TISSUE BY BALL INDENTATION TECHNIQUE**  
Atsushi Sakuma, Kyoto Institute of Technology |
| 3:45pm        | **EXPERIMENTAL AND NUMERICAL INVESTIGATIONS OF FRACTURE BEHAVIORS OF CERAMIC TISSUE SCAFFOLDS**  
Ali Entezari, University of Sydney |
| 4:00pm - 4:30pm | **Afternoon Tea** |
Musculoskeletal disorders are globally the highest cause of life years lost through disability after mental health disorders. Injury, degeneration, deformity and malignancy are the most important contributors to this disability. St. Vincent’s Hospital Melbourne is the designated State center for arthroplasty and is a National referral center for the treatment of bone and soft tissue malignancies. These two important services underpin the MSK research program at St. Vincent’s which focuses on (i) preventing osteoarthritis, (ii) improving outcomes after joint replacement surgery, and (iii) returning function after limb amputation through advanced reconstructive techniques.

The MSK research program at St. Vincent’s Hospital Melbourne is driven by a multidisciplinary approach that brings together a coalition of cell biologists, polymer scientists, metallurgists, biomedical engineers and surgeons into an arena that combines a number of platform technologies including stem cell biology, biomaterials, advanced bio-fabrication (including 3D printing and electro-spinning), additive manufacturing, mechano-biology and advanced medical imaging.

The products of such a research endeavour include cartilage, bone, osteochondral, ligamentous and tendinous devices. Other outcomes include patient-specific implants, specialized implants that act as vehicles for drug delivery, dissolvable/degradable devices, enhanced fixation of metallic devices and image-guided/robot assisted surgical techniques. The long term vision explores the possibility of rebuilding lost limbs and manufacturing same-day surgery just-in-time implants.

By leveraging advances in technology, and connecting scientists with clinicians at the coal face of activity, this program of research aims to drive translation towards producing clinically and cost-effective solutions for the increasing burden of MSK disorders. The assembly of expert collaborators (Department of Orthopaedics and Surgery, St. Vincent’s Hospital; Intelligent Polymer Research Institute, University of Wollongong; Aerospace, Mechanical and Manufacturing Engineering, Royal Melbourne Institute of Technology; Mechanical and Biomedical Engineering, University of Melbourne; and the Faculty of Science, Technology and Engineering, Swinburne Technical University, and their networks) linked with St. Vincent’s through the BioFab3D@Aikenhead Centre for Medical Discovery creates a unique opportunity for industry to establish a knowledge ad research resource that will lead to further advances and commercialization of implantable and applicable devices, and for patients to receive the most cutting edge advances when scientist and clinicians collide.
INVESTIGATING THE EFFECT OF NANOPARTICLE UPTAKE ON THE ADHESION PROPERTY OF HUMAN CELL

Md Alim Iftekhar Rasel1, Trung Dung Nguyen 2, YuanTong Gu1,

1 School of Chemistry, Physics and Mechanical Engineering, Queensland University of Technology, Brisbane, QLD, Australia
2 Dept. of Aerospace and Mechanical Engineering, College of Engineering, University of Notre Dame, Notre Dame, IN 46556

INTRODUCTION

As a potential biomaterial for medical engineering, boron nitride nanoparticle (BN NP) and Hydroxylapatite (HAP) have drawn significant interest. Their superior physical and chemical properties give them an edge over other nanoparticles [1-2]. However, there are limited studies investigating effect of nanoparticles uptake on the physical properties of cells. For successful utilization of nanoparticles in biomedical engineering applications, normal cellular function as well as mechanical integrity have to be retained.

The ability of cells to adhere to its substrate is a crucial feature of human cells. A number of important cellular activities such as cell orientation, motility, morphogenesis, mitosis, embryogenesis etc. depend on cells ability to adhere to neighbouring cells [3]. In this study, we investigate the effect of BN NP and HAP uptake on the adhesion property of human bone marrow stem cells using Atomic Forced Microscopy (AFM).

METHODS

The cells were cultured in proper environment (using Dulbecco’s Modified Eagle’s Medium, incubated in 37°C with 6% CO2) for 24 h. They were then further cultured with the nanoparticles (BN NP and HAP) with varying concentrations for 24h. Finally they were washed in PBS and tested in AFM.

In AFM, a flexible cantilever of microscopic dimension can be used to displace samples from the substrate and record the deflection. Taking advantage of this, Zhang et al. developed a method to quantify the detachment force of bacteria [4]. In this study, a similar approach is taken to quantify the lateral detachment force (adhesion property) of human bone marrow stem cells. The ACSTG-20 with a spring constant of 7.8 N/m was used as the cantilever which was supplied by AppNano. The AFM cantilever was placed near to the cell periphery (at the centre) by lateral and vertical movement of the cantilever. Once the cantilever is in its proper place, the cell was scanned in contact mode. While scanning, the cell is detached from the substrate and the deflection is recorded. From the deflection curve, the required lateral force is quantified (details in ref [2]).

RESULTS AND DISCUSSION

Initial results show, for a concentration of 50 µg/ml, the adhesion force of cells increases over time for both BN NP and HAP. This means, cells are happily growing and the nanoparticles do not have any impact on the adhesion force. However, once the concentration is increased to 100 µg/ml, the adhesion force of cells seems to decrease significantly. The nanoparticle uptake seems to have a strong impact on the adhesion property of the cells. Further increase of the concentration causes the cells to die and they simply detach from the substrate and starts floating in the medium.

This makes it clear that both BN NP and HAP have significant impact on the adhesion property of the human bone marrow stem cells. Therefore, researchers must be very careful while choosing the appropriate nanoparticle and their quantity in future nanoengineering applications.

CONCLUSIONS

A noble method is developed to quantify the adhesion property of cells after being cultured with nanoparticles (BN NP and HAP). The method is an alternate way of evaluating biological materials and their mechanical safety. Results confirm the effect of both BN NP and HAP uptake on the adhesion property of tested cells. Further study is needed to identify the reasons behind the adhesion force reduction and unravel the underlying mechanism.

ACKNOWLEDGEMENTS

Acknowledgments are optional.

REFERENCES

INTRODUCTION
Identifying suitable 3D scaffolds for repair and regeneration of bone in critical size defects is challenging due to different, often contradictory, requirements imposed on these materials. Ceramic materials have gained increasing use in bone tissue engineering due to their biocompatibility and similar chemical composition as bone. Recently, calcium silicate ceramic containing zirconium, patented under the name Baghdadite, has shown very promising results in terms of biocompatibility [1] and excellent mechanical properties [2]. While scaffold mechanical properties are essential to support the defect at the repair site, the success of the bone graft is strongly governed by the ability of blood vessels and cells to invade the scaffold. Permeability has been shown to play a major role in the promotion of vascularization and bone regeneration in vivo. Material properties of ceramic scaffolds (and bone) decrease with increasing porosity. On the other hand, the permeability of scaffolds (and bone) increases with increasing porosity. Consequently, an optimum range of porosities needs to be identified where both the mechanical properties and the permeability are sufficiently high to warrant efficient bone repair. Identifying this porosity regime is challenging. Here we propose a novel experimental-computational approach to characterise the dependence of material properties and permeability on porosity using Baghdadite as scaffold material.

METHODS
In order to assess dependence of permeability on porosity, Baghdadite scaffolds with dimensions 10 mm in length and 7 mm in diameter with porosity varying from 65 to 95% have been scanned using a desktop microCT scanner. After reconstruction, the volumes are segmented into three phases (solid, fluid, interface). An in-house algorithm maps the segmented images into a 3D mesh. The Stokes equation is solved at the porescale by means of the open source software arb [3]. The porescale velocity and pressure fields are upscaled in order to calculate the full anisotropic permeability tensor.

Furthermore, the stiffness and strength of the samples was investigated by performing uniaxial compression tests with the ElectroForce 5500, Bose. Tests were run under displacement control at 0.5 mm/min with loading until 0.5%, followed by unloading, followed by reloading until fracture. Based on these tests both material stiffness and strength can be calculated. Also the fracture mode was determined based on the obtained load-displacement curves.

RESULTS AND DISCUSSION
The anisotropic permeability tensor is computed for 12 specimen from each group of porosity. The eigenvalues of the upscaled tensor indicate the preferential flow directions of the microstructure. While the low porosity scaffolds exhibited a typical brittle behaviour, the highly porous scaffolds showed a damageable, cellular-like behaviour from the rupture of individual ceramic struts. The functional advantages of different scaffold morphologies are discussed in term of permeability and mechanical strength properties.

CONCLUSIONS
Both the mechanical properties and permeability need to be considered for selection of optimal scaffold porosities for application in critical size bone defects. The experimental-computational approach proposed here provides important information on selection and design of ceramic scaffolds with particular microstructures and mechanical properties to mimic host bone tissue.

ACKNOWLEDGEMENTS
The authors are grateful to Prof Clement and Dr Hardiman from the Melbourne Dental School for the in-kind use of the microCT device.

REFERENCES
INTEREDUCTION

Replacement of bone tissue with metal implant prosthesis is a common surgical procedure for treating bone trauma or illness such as osteosarcoma. The invasive nature of surgery with conventional implants imposes many limitations, including: long hospital stays, postoperative pain, and post-surgery complications [1]. Common post-surgery complications are associated with implant loosening attributable to standard implant limitations in: matching bone mechanical properties; bone-implant integration due to limited bone ingrowth; and not replicating original bone geometry [2]. A mismatch between the implant and bone mechanical properties (particularly stiffness) is especially problematic as it can lead to the phenomenon of stress shielding (i.e., transfer of mechanical loads from bone regions to the implant) and subsequent bone weakening due to the bone adaptation characteristic of Wolff’s law [3]. The ability to address this limitation by controlling the stiffness of standard solid metal implants is limited by constraints associated with conventional manufacturing. However, emerging Additive Manufacturing (AM) techniques such as Selective Laser Melting (SLM) can enable customisation of complex implants based on cellular lattice structures optimised to match patient-specific bone geometry and stiffness; potentially avoiding stress shielding by tuning implant stiffness. The mechanical properties of lattices depend on a number of factors which require experimental evaluation to facilitate effective implant design, including: cell topology, relative density and loading conditions [4].

This work reports on the experimental investigation of stiffness properties of SLM manufactured Titanium (Ti6Al4V) lattice structures of varying cell configurations.

METHODS

A range of lattice cell specimens were SLM manufactured and tested under quasi static compressive loading to measure associated stiffness. The stiffness was measured at initial loading (Young’s modulus) and after reloading (2% strain modulus). The specimens varied in cell topology (Fig.1) and cell size (2 and 3mm).

RESULTS AND DISCUSSION

Current literature typically uses bone tissue Young’s Modulus as the objective function for minimising stress shielding. A number of publications focused on additively manufactured lattices also associate the Young’s modulus with the expected in-situ stiffness of lattice structures, for example [4-5]. However, tests showed that the Young’s modulus is always lower than the reloading moduli at 2% strain (Fig.2). This observation indicates that localised plasticity is occurring in the lattice specimens at stresses below the compressive strength. This outcome is compatible with observations for metallic foams [4], but this work confirms this phenomenon in AM lattice structures. The results indicate that effective lattice implant design needs to target the reloading modulus rather than the Young’s modulus value.

CONCLUSIONS

The discrepancy between loading and reloading modulus can be pronounced for SLM manufactured lattice structures. Consequently, the reloading modulus of AM lattice structures should be used as the optimisation criterion for bone replacement materials. Further work is currently being undertaken to evaluate a broader range of lattice topologies and cell geometries in order to target specific bone stiffness requirements.

REFERENCES


Figure 1: Lattice unit cells (left) and test specimens (right).

Figure 2: Example stress-strain response (left) and modulus values (right) of tested lattice specimens.
TAILORING THE MECHANICAL PROPERTIES OF HYDROGELS FOR CARTILAGE TISSUE ENGINEERING

Cathal D O’Connell1, Peter Pivonka2, Binbin Zhang3, Irene Yu4, Emily Liu5, Claudia Di Bella1,2, Serena Duchí3, Carmine Onofrillo5, Anita Quigley1,4,5, Romane Blanchard1, Justin Bourke1,4,5, Robert Kapsa1,4,5, Peter Choong2,3, Gordon G. Wallace1

1ARC Centre of Excellence for Electromaterials Science, University of Wollongong
2Department of Orthopaedic, St Vincent’s Hospital, Melbourne
3Department of Surgery, St Vincent’s Hospital, University of Melbourne
4Department of Medicine, University of Melbourne, Melbourne
5Department of Clinical Neurosciences, St Vincent’s Hospital, Melbourne

INTRODUCTION

Osteoarthritis (OA) is one of the most debilitating diseases in the developed world, affecting 80% of people over 65, and costing the Australian economy over $2 billion per year.[1] The precursor to OA in the knee joint is a chondral defect(s) which can manifest and grow over a period of decades, but for which there is currently no effective clinical strategy to repair.[2] One exciting possibility to prevent onset of OA is to regenerate natural effective clinical strategy to repair. One exciting patient.[3] This approach is dependent on identifying suitable scaffolding materials that allow cells to differentiate along the desired lineage, which can be remodelled to form regenerative cartilage tissue, and which match the native mechanical environment. The challenge is compounded in articular cartilage by the depth dependent change in mechanical properties, such as a 7 fold increase in compressive modulus within 1.5 mm depth.[5] This study develops a methodology to tune the mechanical properties of hydrogels towards new scaffold materials able to fulfill the requirements for successful cartilage tissue engineering.

METHODS

Gelatin methacrylate (GelMa) is naturally derived hydrogel which is crossinkable through free radical polymerisation initiated by the exposure of a photoinitiator to UV light. Our thesis is that the mechanical properties of these hydrogels can be controlled through the degree of crosslinking. The study begins with a calculation of the rate of free radical production from UV degradation of the photoinitiator Irgacure-2959 as measured by UV-vis spectroscopy. In situ rheological measurements are used to quantify the rate of reaction of GelMa hydrogels as a function of light intensity, exposure time and photoinitiator concentration. Final elastic moduli are obtained from mechanical indentation measurements. These empirical data are then generalised through a model derived from the kinetics of free radical polymerisation.

RESULTS AND DISCUSSION

Our results demonstrate how the rate of crosslinking of GelMa can be controlled through manipulation of the photocuring conditions (light intensity, exposure time, photoinitiator concentration, and GelMa concentration) to predictably achieve elastic moduli ranging two orders of magnitude (from less than 1 kPa to more than 200 kPa). These materials can thus be tailored to match the mechanical environment of a range of human tissues from neuronal cells to muscle, skin, and cartilage. The fundamental materials understanding developed in this work is also used to design bespoke biomechanical structures. For example, a mechanical gradient presenting an eight-fold drop in stiffness was established through translating a mask across the sample while photocuring [Figure 1].

CONCLUSIONS

The mechanical properties of photocrosslinkable hydrogels can be tailored through rational control of the degree of crosslinking. Marrying this strategy with advanced biofabrication techniques, such as 3D bioprinting, promises bespoke 3D structures with distributed mechanical properties while also incorporating encapsulated cells.[6] These structures could provide a unique proving ground for next-generation cartilage repair strategies, such as the differentiation of zonal populations of chondrocytes in a layered structure of graded stiffness.

REFERENCES

INTRODUCTION
Mechanical behavior of biological soft tissue is complex because of the internal structure of cells, fiber, intracellular fluid, and so on. Damage and fracture behaviors of soft tissue are especially important to the evaluation of various phenomena in the areas of surgery, sports injury and traffic accidents. For accurate evaluation of the behaviors, objective observation procedure of mechanical test is needed for the development of the methods. However, fundamental tensile testing of soft tissue has many difficulties, including specimen-profile control, chucking of specimens, strain-quantification, and so on. The technique of indentation testing has been developed by extending Hertzian contact theory. However, the fracture of soft tissue has not been studied because of the difficulties of observation and formulation of deformation behavior of the soft tissue. Therefore, the observation of deformation behavior has been considered in this study. In particular, quantification of the fracture of soft tissue is introduced by using the technique of indentation testing.

OBSERVATION OF MECHANICAL BEHAVIOR
The dynamic behavior of the tissue was observed by a test system using airsoft guns. The test system, shown in Figure 1, has an airsoft gun, which shoots plastic balls vertically downward into specimens placed on top of a load cell. The reaction force caused by the ball can be analyzed by strain waves that propagate in the load cell.

Figure 1: Dynamic system for indentation testing for evaluation of biological soft tissue

Typical specimens after indentation tests are shown in Figure 2. The residual profile of the ball-indenter with ductile deformation can be observed by the quasi-static test specimen in Figure 2 (a). On the other hand, brittle deformation is observed in dynamic test as shown in Figure 2 (b).

(a) Quasi-static (b) Dynamic

Figure 2: Typical specimens after indentation tests

As shown in Figure 3, the change in profile of the contact force becomes greater owing to increased indentation rate, and the magnitude of the plateau force also becomes greater.

Figure 3: Analysis of dynamic indentation test

CONCLUSIONS
This result suggests that the deformation amount of fracture is independent of indentation velocity, even if the viscoelastic behavior of the indentation is obvious in the deformation of the soft tissue.

REFERENCES
INTRODUCTION
Excellent biological properties of ceramic scaffolds place them amongst the main candidates for applications of bone and cartilage repair. However, their uses in load-bearing applications have been limited because of their inherent brittleness and relatively low fracture strength. Hence, effective and reliable uses of such scaffolds in clinic or in-vivo models necessitate an insightful analysis of the fracture behavior under critical conditions.

While substantial experimental studies have been conducted to evaluate the fracture strength of tissue scaffolds, little work has been reported in the literature concerning the computational modeling and analysis of fracture behaviors of ceramic scaffolds with the exception for some typical stress analyses using conventional finite element methods (FEM) [1]. Nevertheless, the stress analyses based on the conventional FEM are not able to model cracking process under loading, compromising their capability and reliability for fracture analyses of ceramic structures. In this study, a relatively new numerical method, namely extended finite element method (XFEM) [2], capable of modeling time-dependent cracking process was used to simulate fracture in robocast Sr-HT-Gahnite scaffolds. Moreover, experimental tests were also conducted on fabricated Sr-HT-Gahnite scaffolds to validate the effectiveness of this numerical technique.

METHODS
The Sr-HT-Gahnite scaffolds were fabricated by depositing the formulated in-house Sr-HT-Gahnite inks [3] through a customized nozzle using a robotic deposition device (Hyrel 3D, USA). The scaffolds were composed of orthogonal layers of Sr-HT-Gahnite rods with different porosities. The compressive strength of the scaffolds was tested in the direction parallel to the pore channels (clinically relevant position for the in-vivo implantation).

XFEM was also conducted on the micro-computed tomography (μCT) based models of the fabricated scaffolds. For this purpose, each fabricated scaffold was scanned using SkyScan 1172 (Kontich, Belgium). The image-processing software ScanIP (Simpleware Ltd, Exeter, UK) was used to generate mesh in four-node linear tetrahedral elements based on the +FE Free algorithm in ScanFE (Simpleware Ltd, Exeter, UK). Furthermore, Field emission scanning electron microscopy (FE-SEM) images of specimens were obtained to validate the crack initiation and propagation paths simulated by XFEM.

RESULTS AND DISCUSSION
The results proved that the XFEM solution was significantly more realistic for predicting fracture strength of the scaffolds compared with conventional FEM counterpart; because unlike the conventional FEM, the XFEM enabled the modeling of scaffolds’ structural resistance to crack propagation in line with energy release rate within the material [2]. Moreover, μCT-based numerical analyses predicted more realistic results than post fabrication CAD-based simulations because the μCT-based models better captured the actual specimens by modeling all details of geometric variation resulted from the fabrication process. Furthermore, the capability of XFEM to predict the correct fracture path in ceramic scaffolds was demonstrated through correlating with the field-emission scanning electron microscopy analysis.

CONCLUSIONS
This study showed that XFEM can be used as an effective and reliable tool to model the fracture behaviors of ceramic scaffolds, thereby providing a robust framework for further optimization of load bearing tissue scaffolds in silico.

ACKNOWLEDGEMENTS
The support from Australian Research Council is grateful.

REFERENCES
<table>
<thead>
<tr>
<th>Time</th>
<th>Session 2 - CLINICAL &amp; SPORTS BIOMECHANICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chairs: Morgan Sangeux (Murdoch Childrens Research Institute), Adam Bryant (University of Melbourne)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 4:30pm - 6:30pm</th>
</tr>
</thead>
</table>
| KEYNOTE SPEAKER | YOUNG PEOPLE WITH OLD KNEES: BIOMECHANICS OF KNEE JOINT DEGENERATION FOLLOWING ACL RECONSTRUCTION  
Associate Professor Adam Bryant, University of Melbourne |

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 5:00pm</th>
</tr>
</thead>
</table>
| VALIDITY AND RELIABILITY OF TRIAXIAL ACCELEROMETERS DURING RUNNING  
Suzi Edwards, University of Newcastle |

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 5:15pm</th>
</tr>
</thead>
</table>
| VALIDATION OF IMU SPRINT DATA: REASSESSING THE ACCELERATION PHASE OVER THE FIRST 30M  
Ethan Moore, Swinburne University / University of Adelaide |

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 5:30pm</th>
</tr>
</thead>
</table>
| TIME TO STABILISATION DURING SINGLE LIMB LANDING IS SHORTER IN PATIENTS WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION  
Jodie McClelland, La Trobe University |

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 5:45pm</th>
</tr>
</thead>
</table>
| PELVIS BIOMECHANICS ARE ALTERED DURING STEP ASCENT IN SYMPTOMATIC FEMOROACETABULAR IMPINGEMENT  
Laura Diamond, Griffith University |

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 6:00pm</th>
</tr>
</thead>
</table>
| MUSCLE CONTRIBUTIONS TO KNEE JOINT MOMENTS IN CHILDREN WITH CEREBRAL PALSY: A TWIN CASE STUDY  
Giorgio Davico, Griffith University |

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 6:15pm</th>
</tr>
</thead>
</table>
| SIMULATING THE EFFECT OF MUSCLE WEAKNESS AND CONTRACTURE ON NEUROMUSCULAR CONTROL OF NORMAL GAIT IN TYPICALLY DEVELOPING CHILDREN  
Aaron Fox, University of Queensland |

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 6:30pm - 7:00pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Time</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 7:00pm - 8:30pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>WELCOME RECEPTION &amp; NETWORKING SESSION at Melbourne Town Hall</td>
<td></td>
</tr>
</tbody>
</table>
Rupture of the anterior cruciate ligament (ACL) results in mechanical and neurophysiological deficits that, in combination, lead to aberrant tibiofemoral (TFJ) kinematics and kinetics. Early ACL reconstruction (ACLR) is commonly performed to improve knee stability and function; however, ACLR is no more successful at preventing knee osteoarthritis (OA) than conservative treatment. Indeed, more than 30% of ACLR patients will show signs of knee OA at 5 years post-surgery and over 50% at 10-20 years post-surgery. Given that ACL injury predominantly occurs in individuals between 15 and 25 years of age, many ACLR patients will exhibit ‘old knees’ well before middle-age.

So what biomechanical factors contribute to the development of premature knee OA following ACLR? Compositional integrity of the knee cartilage-subchondral bone unit depends upon a balance between tissue synthesis and degradation – an interrelationship contingent (in part) upon appropriate joint loading during gait-related activities. A growing number of ACLR-related studies have incorporated computational musculoskeletal models to predict TFJ contact forces during different walking and sporting tasks. In combination with quantitative and semi-quantitative analyses of TFJ magnetic resonance images, several of these studies have also attempted to elucidate the relationship between TFJ contact loading and cartilage-subchondral bone unit structure in the years following ACLR. Results from our ACLR studies and others will be presented.

REFERENCES
VALIDITY AND RELIABILITY OF TRIAXIAL ACCELEROMETERS DURING RUNNING

Suzi Edwards1,2, Seaton Humphries3, Sam White1, Robert Robergs2,3 and Nicholas O’Dwyer2,4
1 School of Environmental and Life Sciences, University of Newcastle, Ourimbah, NSW, Australia
2 School of Exercise Science, Sport and Health, Charles Sturt University, Bathurst, NSW, Australia
3 School of Exercise and Nutrition Sciences, Queensland University of Technology, QLD, Australia
4 Dept. Exercise and Sports Science, University of Sydney, Sydney, NSW, Australia

INTRODUCTION
Triaxial accelerometers embedded in global positioning system (GPS) units are currently increasing in popularity as an alternative method to quantify field sports performance. The reliability of GPS accelerometers has been established when attached to a rigid body [1]. Nevertheless when attached to non-rigid bodies, the reliability of these GPS accelerometer derived variables are questionable as it consistently over-estimates the magnitude of acceleration [2], most likely due to the attachment method of the GPS unit on the body. The superior location of the GPS unit (between T1-T6) and the role of acceleration attenuation also questions the validity of using GPS devices to estimate variables based on the acceleration of the centre of gravity of the body (COG) such as energy expenditure or vertical ground reaction force. Therefore, the aim of this study was to determine the validity and reliability of GPS unit accelerometer to estimate peak vertical COG and thoracic acceleration when compared to the gold standard measure of a three-dimensional (3D) motion capture system.

METHODS
Eleven amateur rugby union players performed 10 successful linear running trials at three different running speeds (slow=3.3m·s⁻¹, medium=5.0m·s⁻¹, fast=6.7m·s⁻¹) wearing a Catapult Optimeye S5 GPS unit (CAT). Kinematic and kinetic data were recorded by a 10-camera Qualisys motion capture system and two Kistler force platforms, respectively. Markers were placed on the limbs, torso, pelvis, head and GPS device to estimate the COG (Model-COG), thoracic (UpTrunk) and 3D-GPS unit segment accelerations. Two Delsys accelerometers were attached laterally to the GPS device on the harness (Harness-Accel) and skin (Skin-Accel). Stance phase was defined from initial contact, to the first vertical acceleration peak (AccMAX1), to the second peak in vertical acceleration (AccMAX2) to toe-off. Validity was assessed with a repeated measures factorial analysis of variance (P<0.05). Reliability was measured by the change in mean, typical effort of measurement (TEM) and intraclass correlation (ICC).

RESULTS AND DISCUSSION
Both AccMAX1 and AccMAX2 displayed a main effect of type (F3,35=69, P<0.01; F3,35=33, P<0.01), speed (F2,29=9, P<0.01; F2,29=29, P<0.01) and interactions between type x speed (F10,110=11, P<0.01; F1,110=17, P<0.01; respectively, Figure 1). Whilst most post-hoc tests were significantly different, there was no significant difference between the 3D-GPS and Harness-Accel with excellent reliability for ICC (0.82-0.97), low TEM (6%-17%) and change in mean (2%-10%) for AccMAX2 for all speeds. Nevertheless, all speeds of AccMAX1 displayed poor reliability for ICC (0.01-0.25), high TEM (19%-39%) and change in mean (29%-66%). Low reliability was observed between the UpTrunk and Accel-harness or Accel-Skin with poor ICC (0.01-0.37), high TEM (13%-97%) and change in mean (13%-66%). Together these findings indicates a substantial inconsistent effects of the movement of the harness and skin relative to the UpTrunk and the CAT within the harness pouch, highlighting the critical need to develop a new attachment method.

The only other non-significant post-hoc tests were CAT and Harness-Accel at medium speed and, Model-COG and UpTrunk at fast speed, highlighting that the validity was depended on running speed. Whilst peak acceleration increased with increased speed (e.g. Model-COG), thoracic derived acceleration variables did not reflect this pattern, most likely due to the changing effect of the limbs with gait speed to magnitude of the COG [3]. The CAT displayed poor reliability to estimate Model-COG for AccMAX1 (except slow) and AccMAX2 with poor ICC (0.03-0.36), high TEM (17%-53%) and change in mean (2%-102%), suggesting CAT is not a reliable nor valid indicator of vertical COG acceleration.

The effect of sampling rate (CAT 100 Hz vs 3D-GPS 300 Hz) on the reliability of AccMAX1 and AccMAX2 showed there was excellent to good-to-fair reliability for ICC (0.68-0.97), suggesting no effect of sampling rate on the reliability of the magnitude of peak acceleration. However, this was not reflected in the poor validity nor high TEM (6%-40%) and change in mean (10%-68%) for all speeds.

CONCLUSIONS
GPS unit accelerometer demonstrated poor reliability and validity to estimate both peak vertical COG and thoracic, highlighting the critical need to develop a new attachment method. Using peak vertical thoracic acceleration to estimate of peak vertical COG acceleration is not valid nor reliable and warrants the development of algorithms to account for the superior location of thoracic-mounted accelerometers to quantify field sports performance.

REFERENCES
VALIDATION OF IMU SPRINT DATA: REASSESSING THE ACCELERATION PHASE OVER THE FIRST 30m

Lucy Parrington¹, Ethan Moore², Elissa Phillips³, Luke Champion¹, Andrew Wong⁴, Mark Finch⁴ and Clare MacMahon¹

¹School of Health Sciences, Swinburne University of Technology, VIC, Australia, lparrington@swin.edu.au
²School of Mechanical Engineering, University of Adelaide, SA, Australia
³Australian Institute of Sport, Canberra, Australia
⁴iMeasureU, Auckland, New Zealand

INTRODUCTION

Wearable technologies have become a popular method of tracking lifestyle activities in the general population. Microsensor inertial measurement units (IMUs) are becoming increasingly utilised within athletic populations, because of the ease of use (i.e. attachment to the body, wireless connectivity, intuitive apps). Furthermore, IMUs have been shown to provide accurate and meaningful data for various components of walking, running and swimming biomechanics [1 - 3].

As part of a larger study, evaluation of 100m sprint data using discrete point analyses demonstrated decreased accuracy for the first two 10m splits during the acceleration phase of the sprint [4]. The purpose of this paper is to re-evaluate the IMU accuracy for the first 30m using root mean square error analyses, with Laveg laser data as the reference.

METHODS

Five competitive athletes from sprint based sports were recruited to run eight 100m sprints. An IMU (iMeasureU, Auckland, New Zealand) was placed on the middle of the lower back at the height of the posterior superior iliac spine. The sensor collected tri-axial acceleration, angular velocities and magnetic flux data (500Hz). A Laveg laser (LAVEG Sport, Jenoptik, Germany) was used to collect criterion data for comparison (100Hz).

Following collection procedures, data were imported into Matlab for processing. Global orientation and drift adjustment of IMU data were calculated, as described elsewhere [4]. Prior discrete point analysis of the data demonstrated higher errors for the first two splits. Thus, to gain further understanding of the overall error for the acceleration phase, IMU accuracy for the first 30m was calculated using root mean square error (RMSE). Mean and standard deviation results were calculated per participant.

RESULTS AND DISCUSSION

Mean and standard deviation RMSE values for IMU against the Laveg laser reference are provided in Table 1. When RMSE was normalised as a percentage of the peak speed, this ranged from 10% to 13%. As an indicator, these values fit within the ranges of other studies assessing inertial sensor accuracy [1]. As a general measure the IMUs provide an adequate estimate of the velocity profile for this acceleration phase.

From an applied sporting perspective, however, there is a need for smaller margins of error; the difference between winning and losing a race can be within milliseconds. Thus, improving the IMU algorithm for calculation of the acceleration phase of the sprint is an important step in the refinement of these devices, if they are to be put to use with elite athletes.

To address issues of the IMU accuracy for the acceleration phase of the sprint, collection specifically on the first 30m has been conducted on a further 12 participants. This dataset includes VICON 3D motion capture of the pelvis as well as timer-gate data to evaluate better ways to curve fit this phase of the algorithm. Data from this analysis will be included in the conference presentation.

CONCLUSIONS

The IMUs have qualities that make them highly desirable for use in applied testing settings, such as the simplicity of use and the ability for coaches and athletes to receive prompt feedback. This study found that the accuracy of the IMUs over the first 30m of the sprint was moderate, but could be improved. Further algorithm development on this initial distance of the sprint should be conducted to increase the accuracy of the acceleration stage of the sprint.

REFERENCES


Table 1: RMSE (mean across 8 trials and SD) and percentage error (mean/peak velocity) per participant.

<table>
<thead>
<tr>
<th>Participant</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.90 ± 0.25</td>
<td>1.09 ± 0.23</td>
<td>1.17 ± 0.34</td>
<td>1.01 ± 0.17</td>
<td>1.22 ± 0.28</td>
</tr>
<tr>
<td>% error</td>
<td>10%</td>
<td>11%</td>
<td>12%</td>
<td>10%</td>
<td>13%</td>
</tr>
</tbody>
</table>

10th Australasian Biomechanics Conference, University of Melbourne, Australia, 4 – 6 Dec 2016
INTRODUCTION
People with reconstruction of the anterior cruciate ligament (ACL) are at a greater risk of subsequent knee injury than the general athletic population. For younger athletes and males, this risk is further elevated. The reasons for this elevated risk of knee injury are multifactorial, however, the movement strategies adopted by these athletes are likely to play a significant role in the development of knee injury subsequent to the initial ACL reconstruction.

ACL injuries are commonly sustained during sports participation when the athlete’s weight is supported by a single limb, either when landing from an elevated height, or when changing direction. Biomechanical analyses have described that patients with anterior cruciate ligament reconstruction demonstrate knee biomechanics that are different from normal during tasks that require landing on a single limb (REF). For more accurate evaluation of knee injury risk, it may be more important to identify whether there are differences in the biomechanics of the whole body during single limb landings. The time that it takes for patients to stabilise their bodyweight may be an appropriate indication of whole body neuromuscular control. Recently, the time to stabilisation has been described as the sole predictive factor in people who sustain ACL injuries. Yet, this has not been described in people with a previous reconstruction.

The aim of this study was to compare the time to stabilisation during a single limb landing task between young athletes with ACL reconstruction and age-matched controls. A secondary aim of the study was to compare the biomechanics of lower limb joints, pelvis and trunk during the same task.

METHODS
Thirty-one participants were included: 18 had undergone ACL reconstruction at least 18 months prior to testing and had returned to play in their main sport, and 13 were of similar age and activity level without knee injury. Participants were asked to perform a single hop where they travelled in a forwards direction the distance of their leg length and the height of half of the maximum jump height. Following a familiarisation period, participants repeated the task until they had completed six successful attempts where they maintained their balance for at least 3 seconds on landing.

The ground reaction force of the landing phase was recorded using an AMTI force platform (AMTI, Watertown, MA, USA) at a sampling rate of 4000Hz. Simultaneously, a 10 camera Vicon Motion Analysis System (Vicon, Oxford, UK) recorded trajectory data from 33 passive reflective markers attached to bony landmarks. Joint angles were estimated based on the modified Helen Hayes model (REF) and a custom trunk model (described relative to the global coordinate system) (REF), and joint moments were calculated using the principles of inverse dynamics. The biomechanics of the lower limb and trunk at initial contact, as well as the peak biomechanics during the first second of landing were identified. Time to stabilisation was quantified as the time required for the vertical component of the ground reaction force to reach and remain within ±5% of the participant’s bodyweight on landing. All data were compared between the operated limb of patients and a randomly assigned limb of control participants using independent t-tests.

RESULTS AND DISCUSSION
Participants with ACL reconstruction were not significantly different from controls in age (17.4±2.1 years vs 18.6±1.2 years; p=0.06), height (176.0±7.9cm vs 175.8±9.1cm, p=0.95) or weight (76.5±12.17kg vs 67.7±10.1kg, p=0.08).

The time to stabilisation was quicker in the ACL reconstruction than control group (0.57±0.11secs vs 0.66±0.12secs, p=0.04). At initial contact with the force platform, patients with ACL reconstruction had greater hip flexion (34.7±5.8 vs 27.0±6.3, p<0.01) and greater anterior pelvic tilt (19.1±4.5 vs 13.1±5.7, p<0.01). The peak biomechanics and lower limb joint moments were not different between groups.

CONCLUSIONS
Younger athletes with anterior cruciate ligament reconstruction adopt single limb landing strategies that are different from normal. Greater pelvis anterior tilt and hip flexion at initial contact support recent evidence that aberrant movement strategies in patients with anterior cruciate ligament reconstruction manifest at more proximal joints to the knee. The shorter time to stabilisation may reflect adoption of an abnormal bracing strategy during landing.

ACKNOWLEDGEMENTS
The authors wish to thank Mr Gustaf Gauffin and Ms Anna Nilsson for their assistance with data collection.
PELVIS BIOMECHANICS ARE ALTERED DURING STEP ASCENT IN SYMPTOMATIC FEMOROACETABULAR IMPINGEMENT

Laura Diamond1,2, Paul Hodges3, Tim Wrigley1, Rana Hinman1, Michelle Hall1, John O’Donnell4, Kim Bennell1

1The University of Melbourne, Centre for Health, Exercise and Sports Medicine, VIC, Australia
2Griffith University, School of Allied Health Sciences & Menzies Health Institute, QLD, Australia
3The University of Queensland, Centre of Clinical Research Excellence in Spinal Pain, QLD, Australia
4St Vincent’s Hospital, East Melbourne, VIC, Australia

INTRODUCTION

FAI is increasingly recognised as a significant cause of hip pain and reduced function in younger active adults [1]. Evidence to support FAI as a risk factor for the future development of hip osteoarthritis is mounting [2]. The absence of experimental data regarding the physical impairment associated with symptomatic FAI hinders the development of optimal treatments. To date, hip function in these patients, assessed primarily during gait, has not been well defined. This study aimed to determine whether hip, pelvis, and trunk biomechanics differ between individuals with and without symptomatic FAI during a step ascent task.

METHODS

Fifteen participants diagnosed with symptomatic cam-type or combined (cam plus pincer) FAI who were scheduled for arthroscopic surgery and 11 age-, and sex-matched pain-free controls (with no evidence of morphological FAI on MRI) underwent three-dimensional motion analysis (Vicon, Oxford, UK) during a step-up task. Participants stood with one foot on each of two floor-embedded force platforms (AMTI OR6-6-2000 Advanced Medical Technology, MA, USA) and stepped up onto a force platform mounted on a step (height=240mm; Kistler 9286AA). Participants performed five trials leading with the symptomatic/test leg. Trunk, pelvis, and hip kinematics, and hip kinetics, during the stance phase were compared between groups using an analysis of covariance, with leg length as a covariate (p<0.05).

RESULTS AND DISCUSSION

The FAI and control groups were comparable for age, height, sex and BMI (Table 1). Sporting activity level (Tegner activity scale) was significantly higher in the control group at the time of testing (p=0.04). There were no significant between-group differences in trunk or hip kinematics, or hip kinetics. Participants with FAI demonstrated 32% greater pelvic rise on the symptomatic side at heel contact with the step (p<0.05) and 34% greater after lifting the trailing leg during single-leg support (p<0.05) compared to controls (Figure 1).

Figure 1: Ensemble average (± standard deviation) pelvic obliquity patterns during the stance phase of step ascent for control (blue) and FAI (red) participant groups. The vertical line indicates the beginning of single-leg support.

The hip abductor muscles have an important role in optimising the position of the pelvis relative to the femur during single leg weight bearing tasks and are thus critical to prevent movement into a position that impinges the hip. Increased pelvic rise on the symptomatic side (pelvic obliquity) in individuals with symptomatic FAI may be a consequence of abductor muscle weakness (previously reported in these patients [3]). Although the implications of these findings for symptoms and function are not yet clear, they may suggest a compensatory strategy with possible long-term consequences (e.g. increased load on adjacent joints or the contralateral hip; sustained muscle weakness leading to suboptimal joint mechanics).

CONCLUSIONS

Biomechanical alterations are evident at the pelvis during step ascent in individuals with symptomatic FAI. These biomechanical changes may put additional stress on adjacent regions and have relevance for rehabilitation.

REFERENCES


Table 1: Demographic and clinical characteristics for femoroacetabular impingement (FAI) and control groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yrs)</th>
<th>Males</th>
<th>Height (m)</th>
<th>BMI (kg/m²)</th>
<th>FAI type</th>
<th>Dominant side tested, n(%)</th>
<th>Tegner Activity Level (0-10)</th>
<th>Pain (0-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAI (n=15)</td>
<td>24.7 (4.9)</td>
<td>11 (73%)</td>
<td>1.76 (0.09)</td>
<td>24.4 (2.5)</td>
<td>11:4</td>
<td>10 (67%)</td>
<td>5.2 (2.1)*</td>
<td>1.3 (1.4)</td>
</tr>
<tr>
<td>Control (n=11)</td>
<td>26.0 (4.5)</td>
<td>8 (72%)</td>
<td>1.78 (0.08)</td>
<td>23.6 (2.0)</td>
<td>-</td>
<td>6 (54%)</td>
<td>6.7 (1.0)*</td>
<td>-</td>
</tr>
</tbody>
</table>

Values are mean (standard deviation) unless otherwise stated; *p<0.05.
MUSCLE CONTRIBUTIONS TO KNEE JOINT MOMENTS IN CHILDREN WITH CEREBRAL PALSY: A TWIN CASE STUDY
Giorgio Davico1, Claudio Pizzolato1, Steve Obst1, David Lloyd1, Christopher Carty1
1 School of Allied Health Sciences and Menzies Health Institute Queensland, Griffith University, QLD, Australia

INTRODUCTION
Cerebral palsy (CP) is a non-progressive disorder of the neuromuscular system caused by damage to the brain during early development. Compared to typically developed children, those with CP have impaired gait due to their abnormal motor control and altered muscle growth [1].

Musculoskeletal (MSK) modelling is emerging as a useful clinical tool, providing insight into the mechanisms that contribute to pathological gait. Muscle force contributions to gait are of particular interest in the evaluation of MSK disorders and can also be used to quantify joint loading [2]. Static optimisation is commonly used to resolve muscle force contributions in MSK models; however, this method may not be appropriate for pathological gait when minimising the sum of squared muscle activations, since muscle activations in CP are quite aberrant with high levels of co-contraction.

We recently assessed the gait of two identical twins, one who was typically developed and the other with CP. The aim of this case study was to determine muscle force contributions at their knees during gait using both static optimisation and an electromyogram (EMG)-driven approach with a specific focus of muscles that actuate the knee joint. We hypothesised that muscle force contributions would be similar between the twins when using static optimisation but larger in the CP twin when adopting the EMG-driven approach.

METHODS
Two twin brothers (13 yo), one typically developed (height = 169.0 cm, mass = 59 kg) and one with CP (height = 171.8 cm, mass = 59 kg) were recruited as part of a larger study approved by the Griffith University Human Research Ethics Committee.

Reflective markers were attached to the trunk, pelvis and lower limbs in accordance with [3] and EMG electrodes were placed on the Gastrocnemii, Soleus, Tibialis Anterior, Semimembranosus, Biceps Femoris, Sartorius, Tensor Fasciae Latae, Gracilis, Vastus Medialis and Lateralis and Rectus Femoris muscles. Participants first walked on a treadmill at three speeds and then performed overground walking at preferred walking speed, maximal vertical jump and calf raise trials.

Marker trajectory reconstruction and labelling were performed in Vicon Nexus (v2.3). EMG signal processing and definition of the maximal muscle activation was performed in MOtoNMS. MSK model scaling (Gait2392), inverse kinematics, inverse dynamics, muscle analysis and static optimisation was performed in OpenSim (v3.3) and EMG-driven analysis was performed using CEINMS [4]. Musculotendon and activation parameters were calibrated prior to the EMG-driven analysis [5]. Dependent variable included ankle and knee joint kinematics and kinetics, and summed muscle force contributions to the knee joint moment using static optimisation and CEINMS.

RESULTS AND DISCUSSION
The results are for one walking trial at preferred walking speed on the treadmill. The twin with CP had increased ankle plantarflexion and knee flexion during mid-stance with associated increased ankle plantarflexion and knee extension moments compared to his twin brother.

Static optimisation results showed a large contribution from the knee extensor muscles during mid-stance in the twin with CP to overcome the internal knee extension moment (Figure 1A). In comparison, EMG-driven muscle simulations revealed an overall increased forces produced by both knee flexors and extensors throughout the stance phase of the gait for both twins, with the CP twin again demonstrating a larger contribution from the knee extensors during mid-stance (Figure 1B).

![Figure 1: Knee extensor and flexor muscles contributions to the knee joint moment throughout gait estimated using (A) static optimisation, and (B) EMG-driven approaches. Typically developed = solid line, CP = dashed line.](image)

CONCLUSIONS
The summed force contribution of the knee extensor and flexor muscles in typical developed and CP gait may be underestimated using static optimisation. Thus, the corresponding joint contact forces calculated may also be underestimated. Moreover, our results demonstrate the ability of CEINMS to account for additional muscle co-contraction in both typical paediatric and CP gait, which would be expected for both when walking on a treadmill.

REFERENCES
INTRODUCTION
Cerebral palsy (CP) is caused by a lesion to the brain at or near the time of birth. Patients with hemiplegic CP often demonstrate an equinus gait pattern (i.e. toe-walking) during the stance and/or swing phase of gait [1]. Musculoskeletal modelling and simulation have become useful tools for evaluating pathological control of gait [2]. Muscle weakness and contracture are two common musculoskeletal deficiencies linked to CP [3,4]. Conducting simulations with muscle properties that resemble these deficiencies may elicit further understanding of the control strategies required, or factors that limit normal gait in this population. This may assist in developing targeted interventions aimed at improving gait function in children with CP. The purpose of this study was to examine the effect of simulated muscle weakness and contracture on the neuromuscular requirements for achieving normal walking gait.

METHODS
Nine typically developing children (10.0 ± 2.1 yrs; 140.2 ± 22.13 cm; 28.8 ± 10.5 kg) with no known gait abnormalities participated in this study. Three-dimensional kinematics and kinetics were collected during three trials of overground walking at a self-selected speed. Muscle-driven simulations of a representative gait cycle for the right leg were generated from each trial using OpenSim 3.3. The segment lengths and muscle strength of a generic musculoskeletal model of the pelvis and lower limbs were scaled to each participant. Joint angles and moments were calculated using inverse kinematics and dynamics, with dynamic inconsistencies resolved via application of a residual reduction algorithm. The muscle excitations required to drive the simulation were then estimated using computed muscle control.

Additional muscle-driven simulations of gait were generated for each participants trials using altered muscle parameters. The medial and lateral gastrocnemius, soleus and tibialis anterior were progressively weakened by reducing the maximal isometric force by 15% and 30%. The tendon slack lengths of the medial and lateral gastrocnemius, and soleus were shortened by 1.5% and 3.0% to simulate muscle contracture (i.e. increased effective stiffness). All combinations of muscle weakness and contracture were tested, resulting in nine muscle-driven simulations per trial. Reserve actuators were included for each degree of freedom to ensure simulations ran where the muscles could not generate sufficient torques. Muscle activations and forces from the simulations were examined and compared.

RESULTS AND DISCUSSION
Muscle activations and forces generated by the muscles crossing the hip and knee were largely unaffected by the simulated changes in muscle strength and stiffness, and large contributions (i.e. > 5% of the peak joint moment) of reserve actuators at the hip and knee were not required across any simulations.

Shorter tendon slack lengths without a concomitant reduction in muscle strength was the major limiting factor in being able to achieve normal gait within the activation constraints of the calf muscles. Large reserve torques were required at the ankle during the initial swing phase of gait under these simulation conditions. The increased resistance to stretch combined with normal strength resulted in larger passive forces from the plantarflexors during the initial swing phase and prevented the ankle from shifting to a dorsiflexed position without additional assistance from reserve actuators. Strengthening of the plantarflexors may need to be balanced by reductions in stiffness or simultaneous strengthening of the dorsiflexors to promote normal gait in children with CP.

The maintenance of normal gait appeared robust to muscle weakness in isolation or when combined with shorter tendon slack lengths. The main compensation for isolated muscle weakness was to increase the activation of the weakened muscle, similar to previous findings [5]. Combined muscle weakness and contracture resulted in reduced activation of the gastrocnemii during the stance phase of gait, with lower activations required with greater effective stiffness. The passive tension generated by the stiffened plantarflexors through mid-stance likely reduced the need to generate active force during this phase of gait. While neuromuscular adaptations to maintain normal gait were identified, children with CP may be unable to employ these. Across all simulations, the activation patterns and levels used may not be voluntarily achievable by children with CP [1,4].

CONCLUSIONS
Normal gait may be attainable with weak and contractured muscles. However, improvements in neuromotor control of the lower limb are likely required for this to be achievable by children with CP.

REFERENCES
<table>
<thead>
<tr>
<th>First Name</th>
<th>Last Name</th>
<th>Institution / Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>David</td>
<td>Ackland</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>N. Ekin</td>
<td>Akalan</td>
<td>Istanbul University</td>
</tr>
<tr>
<td>Kim</td>
<td>Allison</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Morris</td>
<td>Ark</td>
<td>University of Sydney</td>
</tr>
<tr>
<td>Thiranja</td>
<td>Babarendra Gamage</td>
<td>University of Auckland</td>
</tr>
<tr>
<td>Jasvir</td>
<td>Bahl</td>
<td>University of South Australia</td>
</tr>
<tr>
<td>Sarah</td>
<td>Barns</td>
<td>Queensland University of Technology</td>
</tr>
<tr>
<td>Rod</td>
<td>Barrett</td>
<td>Griffith University</td>
</tr>
<tr>
<td>Martina</td>
<td>Barzan</td>
<td>Griffith University</td>
</tr>
<tr>
<td>Christian</td>
<td>Bauer</td>
<td>Event Photographer</td>
</tr>
<tr>
<td>Thor</td>
<td>Besier</td>
<td>University of Auckland</td>
</tr>
<tr>
<td>Lynne</td>
<td>Bilston</td>
<td>Neuroscience Research Australia</td>
</tr>
<tr>
<td>Samantha</td>
<td>Birse</td>
<td>La Trobe University</td>
</tr>
<tr>
<td>Stephanie</td>
<td>Blair</td>
<td>Victoria University</td>
</tr>
<tr>
<td>Carina</td>
<td>Blaker</td>
<td>University of Sydney</td>
</tr>
<tr>
<td>Romane</td>
<td>Blanchard</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Pavel</td>
<td>Bogachko</td>
<td>Qualisys</td>
</tr>
<tr>
<td>Bart</td>
<td>Bolsterlee</td>
<td>Neuroscience Research Australia</td>
</tr>
<tr>
<td>Sara</td>
<td>Brice</td>
<td>James Cook University</td>
</tr>
<tr>
<td>Warren</td>
<td>Brooks</td>
<td>Kistler</td>
</tr>
<tr>
<td>Adam</td>
<td>Bryant</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Pascal</td>
<td>Buenzli</td>
<td>Monash University</td>
</tr>
<tr>
<td>Dianne</td>
<td>Cameron</td>
<td>Monash Health</td>
</tr>
<tr>
<td>Christopher</td>
<td>Carty</td>
<td>Griffith University</td>
</tr>
<tr>
<td>Luke</td>
<td>Champion</td>
<td>Swinburne University</td>
</tr>
<tr>
<td>Aaron</td>
<td>Chin</td>
<td>Vicon</td>
</tr>
<tr>
<td>Rachel</td>
<td>Choi</td>
<td>University of Sydney</td>
</tr>
<tr>
<td>Julie</td>
<td>Choisne</td>
<td>University of Auckland</td>
</tr>
<tr>
<td>Peter</td>
<td>Choong</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Alexander</td>
<td>Christov</td>
<td>St Vincent’s Hospital Melbourne</td>
</tr>
<tr>
<td>Elizabeth</td>
<td>Clarke</td>
<td>University of Sydney</td>
</tr>
<tr>
<td>Matt</td>
<td>Clarke</td>
<td>I Measure U</td>
</tr>
<tr>
<td>John</td>
<td>Clement</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Gino</td>
<td>Coates</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Eduardo</td>
<td>Cofré Lizama</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Celeste</td>
<td>Coltman</td>
<td>University of Wollongong</td>
</tr>
<tr>
<td>David</td>
<td>Cooper</td>
<td>University of Saskatchewan</td>
</tr>
<tr>
<td>Max</td>
<td>Cowen</td>
<td>Logemas</td>
</tr>
<tr>
<td>Loyola</td>
<td>D’Silva</td>
<td>Springer</td>
</tr>
<tr>
<td>Arkiev</td>
<td>D’Souza</td>
<td>Neuroscience Research Australia</td>
</tr>
<tr>
<td>Christian</td>
<td>Daish</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>First Name</td>
<td>Last Name</td>
<td>Institution / Organisation</td>
</tr>
<tr>
<td>------------</td>
<td>-----------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Giorgio</td>
<td>Davico</td>
<td>Griffith University</td>
</tr>
<tr>
<td>Alasdair</td>
<td>Dempsey</td>
<td>Murdoch University</td>
</tr>
<tr>
<td>Laura</td>
<td>Diamond</td>
<td>Griffith University</td>
</tr>
<tr>
<td>Stephen</td>
<td>Dickins</td>
<td>Head to Foot Orthotics</td>
</tr>
<tr>
<td>Ami</td>
<td>Drory</td>
<td>Australian National University</td>
</tr>
<tr>
<td>Suzi</td>
<td>Edwards</td>
<td>University of Newcastle</td>
</tr>
<tr>
<td>Ali</td>
<td>Entezari</td>
<td>University of Sydney</td>
</tr>
<tr>
<td>Ferryanto</td>
<td>Ferryanto</td>
<td>Tokyo Institute of Technology / Institut Teknologi Bandung</td>
</tr>
<tr>
<td>David</td>
<td>Findlay</td>
<td>University of Adelaide</td>
</tr>
<tr>
<td>Aaron</td>
<td>Fox</td>
<td>University of Queensland</td>
</tr>
<tr>
<td>Catherine</td>
<td>Galvin</td>
<td>University of Canberra</td>
</tr>
<tr>
<td>Georgia</td>
<td>Giblin</td>
<td>Queensland Academy of Sport</td>
</tr>
<tr>
<td>Wendy</td>
<td>Gilleard</td>
<td>Southern Cross University</td>
</tr>
<tr>
<td>James</td>
<td>Graham</td>
<td>AIMedical</td>
</tr>
<tr>
<td>Desney</td>
<td>Greybe</td>
<td>University of Auckland</td>
</tr>
<tr>
<td>Yuantong</td>
<td>Gu</td>
<td>Queensland University of Technology</td>
</tr>
<tr>
<td>Daniel</td>
<td>Hageman</td>
<td>University of New South Wales</td>
</tr>
<tr>
<td>Michelle</td>
<td>Hall</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Christopher</td>
<td>Hall</td>
<td>Australian Synchrotron</td>
</tr>
<tr>
<td>Shigeto</td>
<td>Hayashi</td>
<td>Kyoto Institute of Technology</td>
</tr>
<tr>
<td>Pendar</td>
<td>Hazrati</td>
<td>University of Sydney</td>
</tr>
<tr>
<td>Rob</td>
<td>Herbert</td>
<td>Neuroscience Research Australia</td>
</tr>
<tr>
<td>Peta</td>
<td>Hitchens</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Ben</td>
<td>Hoffman</td>
<td>University of Southern Queensland</td>
</tr>
<tr>
<td>Adrienne</td>
<td>Hunt</td>
<td>University of Sydney</td>
</tr>
<tr>
<td>Jennifer</td>
<td>Jackson</td>
<td>Technic Pty Ltd</td>
</tr>
<tr>
<td>Tim</td>
<td>Jarrot</td>
<td>Head to Foot Orthotics</td>
</tr>
<tr>
<td>Corey</td>
<td>Joseph</td>
<td>Monash Health</td>
</tr>
<tr>
<td>Crystal</td>
<td>Kean</td>
<td>Central Queensland University</td>
</tr>
<tr>
<td>Azadeh</td>
<td>Kian</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Bryce</td>
<td>Killen</td>
<td>Griffith University</td>
</tr>
<tr>
<td>Hiroshi</td>
<td>Kinoshita</td>
<td>Osaka University</td>
</tr>
<tr>
<td>Melissa</td>
<td>Knothe Tate</td>
<td>University of New South Wales</td>
</tr>
<tr>
<td>Fred</td>
<td>Koshir</td>
<td>TA Instruments</td>
</tr>
<tr>
<td>Martin</td>
<td>Leary</td>
<td>RMIT University</td>
</tr>
<tr>
<td>Gökçe</td>
<td>Leblebici</td>
<td>Istanbul University</td>
</tr>
<tr>
<td>Peter</td>
<td>Lee</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Gavin</td>
<td>Lenton</td>
<td>Griffith University</td>
</tr>
<tr>
<td>Chloe</td>
<td>Lerebours</td>
<td>Monash University</td>
</tr>
<tr>
<td>Amy</td>
<td>Lewis</td>
<td>University of Adelaide</td>
</tr>
<tr>
<td>Qing</td>
<td>Li</td>
<td>University of Sydney</td>
</tr>
<tr>
<td>Zihui</td>
<td>Li</td>
<td>ETH Zürich</td>
</tr>
<tr>
<td>Glen</td>
<td>Lichtwark</td>
<td>University of Queensland</td>
</tr>
<tr>
<td>First Name</td>
<td>Last Name</td>
<td>Institution / Organisation</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>-----------------------------------------------------</td>
</tr>
<tr>
<td>Bernard</td>
<td>Liew</td>
<td>Curtin University</td>
</tr>
<tr>
<td>Joe</td>
<td>Lynch</td>
<td>Australian National University</td>
</tr>
<tr>
<td>Jayishni</td>
<td>Maharaj</td>
<td>University of Queensland</td>
</tr>
<tr>
<td>Saulo</td>
<td>Martelli</td>
<td>Flinders University</td>
</tr>
<tr>
<td>Joshua</td>
<td>Mattock</td>
<td>University of Wollongong</td>
</tr>
<tr>
<td>Maciej</td>
<td>Mazur</td>
<td>RMIT University</td>
</tr>
<tr>
<td>Jodie</td>
<td>McClelland</td>
<td>La Trobe University</td>
</tr>
<tr>
<td>Chris</td>
<td>McCosker</td>
<td>Queensland Academy of Sport</td>
</tr>
<tr>
<td>Frank</td>
<td>McGuire MP</td>
<td>Parliamentary Secretary for Medical Research, Victoria</td>
</tr>
<tr>
<td>Patrick</td>
<td>McLaughlin</td>
<td>Novel</td>
</tr>
<tr>
<td>Aaron</td>
<td>Melrose</td>
<td>Victoria University</td>
</tr>
<tr>
<td>Karen</td>
<td>Mickle</td>
<td>Victoria University</td>
</tr>
<tr>
<td>Emma</td>
<td>Millett</td>
<td>New South Wales Institute of Sport</td>
</tr>
<tr>
<td>Patricio</td>
<td>Miranda</td>
<td>University of Queensland</td>
</tr>
<tr>
<td>Ethan</td>
<td>Moore</td>
<td>Swinburne University / University of Adelaide</td>
</tr>
<tr>
<td>Alex</td>
<td>Muir</td>
<td>Logemas</td>
</tr>
<tr>
<td>Chris</td>
<td>Muir</td>
<td>Logemas</td>
</tr>
<tr>
<td>Ralph</td>
<td>Müller</td>
<td>ETH Zürich</td>
</tr>
<tr>
<td>Anna</td>
<td>Murphy</td>
<td>Monash Health</td>
</tr>
<tr>
<td>Kevin</td>
<td>Netto</td>
<td>Curtin University</td>
</tr>
<tr>
<td>Joanna</td>
<td>Ng</td>
<td>University of Wollongong</td>
</tr>
<tr>
<td>Lucy</td>
<td>Ngo</td>
<td>University of New South Wales</td>
</tr>
<tr>
<td>Tam</td>
<td>Nguyen</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Leila</td>
<td>Nuri</td>
<td>Griffith University</td>
</tr>
<tr>
<td>Cathal</td>
<td>O’Connell</td>
<td>University of Wollongong</td>
</tr>
<tr>
<td>Andrea</td>
<td>O’Connor</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Damien</td>
<td>O’Meara</td>
<td>New South Wales Institute of Sport</td>
</tr>
<tr>
<td>Marcus</td>
<td>Pandy</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Elyse</td>
<td>Passmore</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Andrew</td>
<td>Pearce</td>
<td>AIMedical</td>
</tr>
<tr>
<td>Simon</td>
<td>Pearson</td>
<td>Queensland Academy of Sport</td>
</tr>
<tr>
<td>Andre</td>
<td>Pereira</td>
<td>University of New South Wales</td>
</tr>
<tr>
<td>Elissa</td>
<td>Phillips</td>
<td>Australian Institute of Sport</td>
</tr>
<tr>
<td>Peter</td>
<td>Pivonka</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Claudio</td>
<td>Pizzolato</td>
<td>Griffith University</td>
</tr>
<tr>
<td>Leanne</td>
<td>Purcell</td>
<td>Paediatric Gait Analysis Service of NSW</td>
</tr>
<tr>
<td>Timo</td>
<td>Rantalainen</td>
<td>Deakin University</td>
</tr>
<tr>
<td>Aaqil</td>
<td>Rifai</td>
<td>RMIT University</td>
</tr>
<tr>
<td>Bryant</td>
<td>Roberts</td>
<td>Flinders University</td>
</tr>
<tr>
<td>Will</td>
<td>Robertson</td>
<td>University of Adelaide</td>
</tr>
<tr>
<td>Dale</td>
<td>Robinson</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Marcel</td>
<td>Rossi</td>
<td>University of Western Australia</td>
</tr>
<tr>
<td>Atsushi</td>
<td>Sakuma</td>
<td>Kyoto Institute of Technology</td>
</tr>
<tr>
<td>First Name</td>
<td>Last Name</td>
<td>Institution / Organisation</td>
</tr>
<tr>
<td>------------</td>
<td>---------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td>Morgan</td>
<td>Sangeux</td>
<td>The Royal Children's Hospital Melbourne</td>
</tr>
<tr>
<td>Avik</td>
<td>Sarker</td>
<td>RMIT University</td>
</tr>
<tr>
<td>David</td>
<td>Saxby</td>
<td>Griffith University</td>
</tr>
<tr>
<td>Andrew</td>
<td>Schaefer</td>
<td>Charles Sturt University</td>
</tr>
<tr>
<td>Corey</td>
<td>Scholes</td>
<td>EBM Analytics</td>
</tr>
<tr>
<td>Sarah</td>
<td>Shultz</td>
<td>Massey University</td>
</tr>
<tr>
<td>Prasanna</td>
<td>Sritaran</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Julie</td>
<td>Steele</td>
<td>University of Wollongong</td>
</tr>
<tr>
<td>Kathryn</td>
<td>Stok</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Christopher</td>
<td>Sutton</td>
<td>Tracklab</td>
</tr>
<tr>
<td>David</td>
<td>Thomas</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Doreen</td>
<td>Thomas</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Cassandra</td>
<td>Thompson</td>
<td>Western Sydney University</td>
</tr>
<tr>
<td>Alessandro</td>
<td>Timmi</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Silvia</td>
<td>Trichilo</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Logan</td>
<td>Wade</td>
<td>University of Queensland</td>
</tr>
<tr>
<td>Sarah</td>
<td>Ward</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Amy</td>
<td>Waters</td>
<td>Australian Institute of Sport</td>
</tr>
<tr>
<td>Lindsay</td>
<td>Welch</td>
<td>James Cook University</td>
</tr>
<tr>
<td>Benchawan</td>
<td>Wiwatapataphee</td>
<td>Curtin University</td>
</tr>
<tr>
<td>Elizabeth</td>
<td>Wojciechowski</td>
<td>Sydney Children’s Hospitals Network</td>
</tr>
<tr>
<td>Carolina</td>
<td>Wood</td>
<td>‘Talk Me Up’ Marketing</td>
</tr>
<tr>
<td>Tim</td>
<td>Wrigley</td>
<td>University of Melbourne</td>
</tr>
<tr>
<td>Alex Lei</td>
<td>Zhao</td>
<td>University of Auckland</td>
</tr>
</tbody>
</table>