UNIVERSITY OF WATERLOO

OBC 2023

17th Annual (and 20th Anniversary)

Ontario Biomechanics Conference

OBC 2023

Table of Contents

Welcome to OBC 2023!

Welcome to the 20th (17th?) Ontario Biomechanics Conference. It has been four years since we last gathered as a community in March of 2019. Depending how you count this is the fourth time Waterloo has organized the meeting. On behalf of the Department of Kinesiology and Health Sciences at the University of Waterloo we welcome you to OBC 2023 and hope that you share in our excitement for the conference and the chance to network and showcase the novel research being undertaken by the talented biomechanics community in Ontario. The response to the meeting has been overwhelming with 164 abstracts submitted and over 250 registrants.

This year marks a notable change for the meeting. At the inception in 2004, the conference was held in Barrie at the Holiday Inn just off the 400 highway and had 41 abstracts submitted (all podiums at the time). It was picked as a relatively central point between all of universities. It remained at the hotel for the first three years until 2007 when we moved to the Kempenfelt Conference Centre, still in Barrie, due to the rapid growth exceeding the capacity at the Holiday Inn. We grew to take over the whole Kempenfelt facility and again outgrew the capacity and moved to the Nottawasaga Inn Resort in Alliston in 2015. Along the way we reached the capacity of giving every abstract a podium and expanded the opportunity to present by adding poster sessions reaching 180 registrants in 2020 with 115 abstracts. This winter we undertook a survey of biomechanics faculty on the future of OBC given the rising costs of meeting in a conference centre. This year marks another turning point for OBC with a vision that was heavily supported by the survey responses to host the conference at rotating university campuses in the spring between terms.

As mentioned, OBC has grown immensely over the years, but has stayed true to the original goal - to unite biomechanics researchers in Ontario with a unique meeting agenda to be exclusively focused on students. This student-focused conference encourages a collegial and mentoring environment where it is students who present all the science, lead all of the sessions, and ask all of the questions; in essence, students are empowered to drive the conference.

We look forward to a great conference, and we hope you enjoy the social activities that we have planned! We would also like to extend a special thank you and welcome to our Keynote speaker, Dr. David Gabriel who will open the conference on Tuesday night.

On behalf of the conference organizing committee, Waterloo Biomechanics faculty, students, and staff we are looking forward to meeting all of you at the 20th anniversary of OBC.

Sincerely,

Jack Callaghan and Andrew Laing
Conference co-chairs
OBC 2023

Thanks to our Sponsors!

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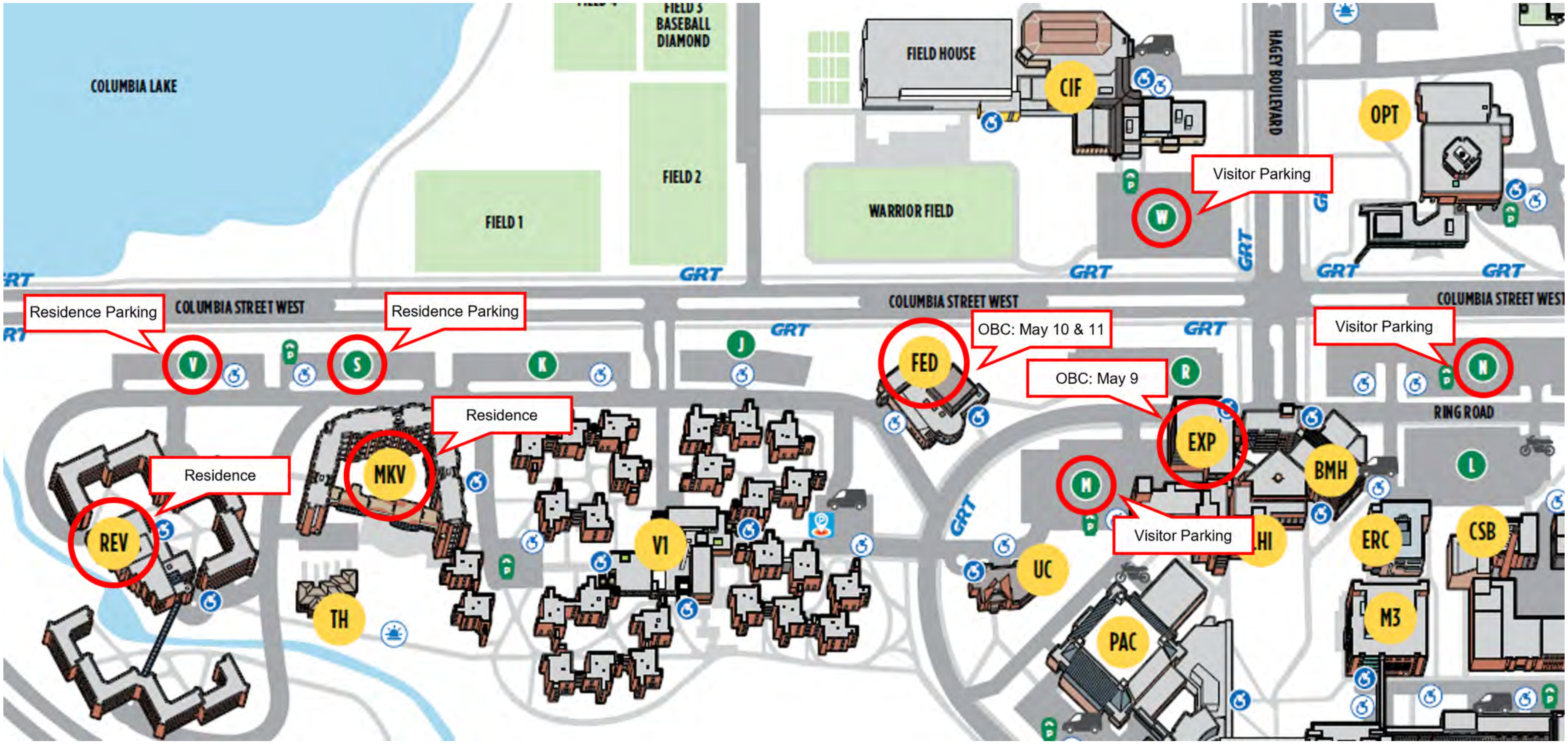
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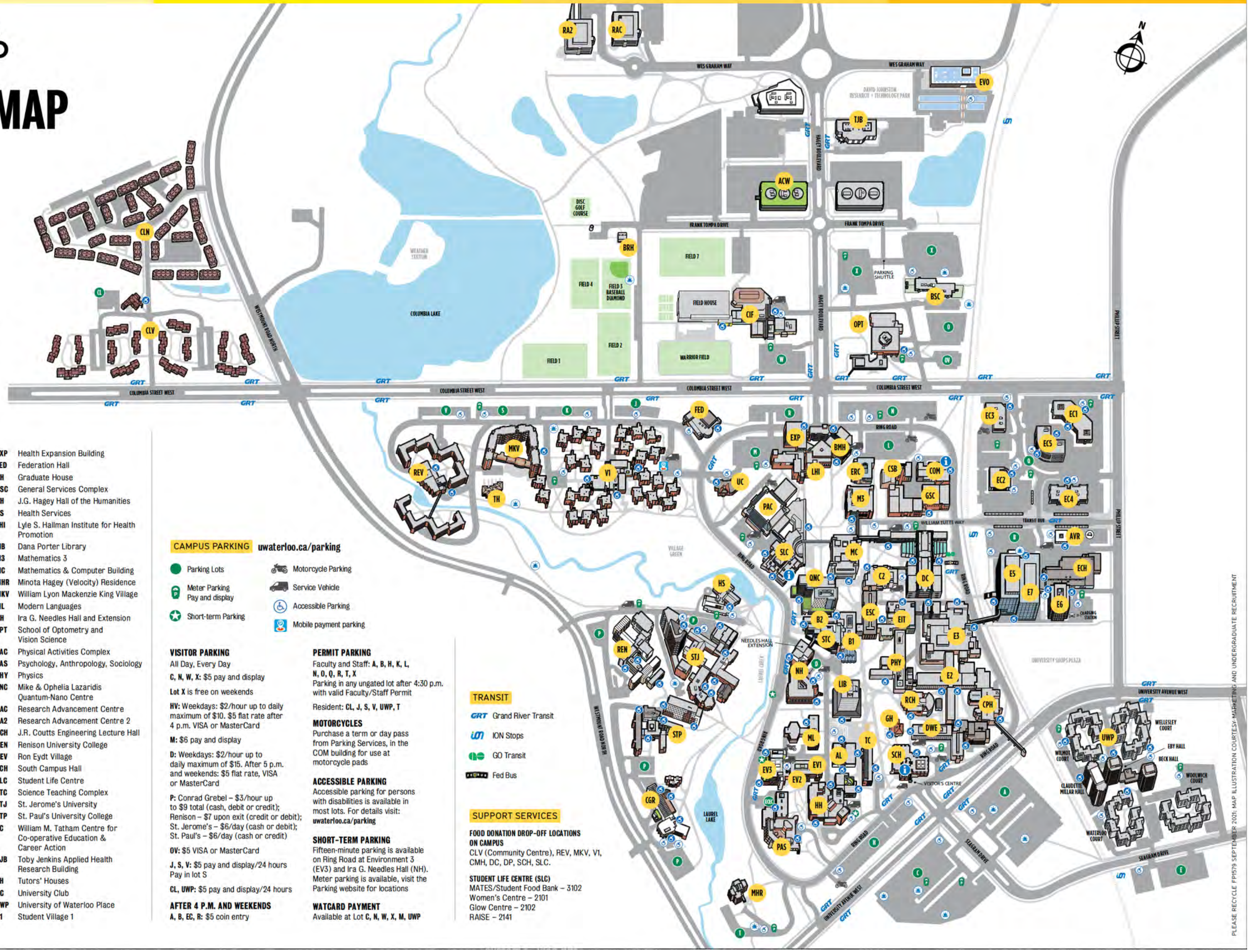
Accessible Entrances
HH Humanities Theatre, Hagey Hall
ML Theatre of the Arts, Modern Languages
SCH Campus Tours, South Campus Hall

BUILDING INDEX

CODE	BUILDING
ACW	Accelerator Centre Waterloo
AL	Arts Lecture Hall
AVR	Autonomous Vehicle Research & Intelligence Laboratory (AVRIL)
B1	Biology 1
B2	Biology 2
BMH	B.C. Matthews Hall
BRH	Brubacher House
BSC	Bright Starts Co-operative Early Learning Centre
C2	Chemistry 2
CGR	Conrad Grebel University College
CIF	Columbia Icefield
CLN	Columbia Lake Village North
CLV	Columbia Lake Village
COG	Columbia Greenhouses
COM	Commissary
CPH	Carl A. Pollock Hall
CSB	Central Services Building
DC	William G. Davis Computer Research Centre
DWE	Douglas Wright Engineering Building
E2	Engineering 2
E3	Engineering 3
E5	Engineering 5
E6	Engineering 6
E7	Engineering 7
EC1	East Campus 1
EC2	East Campus 2
EC3	East Campus 3
EC4	East Campus 4
EC5	East Campus 5
ECH	East Campus Hall
EIT	Centre for Environmental & Information Technology
ERC	Energy Research Centre
ESC	Earth Sciences & Chemistry
EV1	Environment 1
EV2	Environment 2
EV3	Environment 3
EXP	Health Expansion Building
FED	Federation Hall
GH	Graduate House
GSC	General Services Complex
HH	J.G. Hagey Hall of the Humanities
HS	Health Services
LHI	Lyle S. Hallman Institute for Health Promotion
LIB	Dana Porter Library
M3	Mathematics 3
MC	Mathematics & Computer Building
MHR	Minota Hagey (Velocity) Residence
MKV	William Lyon Mackenzie King Village
ML	Modern Languages
NH	Ira G. Needles Hall and Extension
OPT	School of Optometry and Vision Science
PAC	Physical Activities Complex
PAS	Psychology, Anthropology, Sociology
PHY	Physics
QNC	Mike & Ophelia Lazaridis Quantum-Nano Centre
RAC	Research Advancement Centre
RA2	Research Advancement Centre 2
RCH	J.R. Coutts Engineering Lecture Hall
REN	Renison University College
REV	Ron Eydt Village
SCH	South Campus Hall
SLC	Student Life Centre
STC	Science Teaching Complex
STJ	St. Jerome's University
STP	St. Paul's University College
TC	William M. Tatham Centre for Co-operative Education & Career Action
TJB	Toby Jenkins Applied Health Research Building
TH	Tutors' Houses
UC	University Club
UWP	University of Waterloo Place
V1	Student Village 1



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CL, UWP: $5 pay and display/24 hours

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Glow Centre – 2102
RAISE – 2141

Keynote Speaker

David A. Gabriel, Ph.D., FACSM, FNAK
Department of Kinesiology
Brock University

It's OK to have a scientific bias, but it depends on what you do with that bias.

Reflections of a 30-year effort to understand what information about the neural control of muscle is contained within the surface electromyographic signal.

Biography

David Gabriel received a Ph.D. in Biomechanics and Motor Control from McGill University in 1995 and completed an NIH post-doctoral fellowship in Orthopaedic Biomechanics at the Mayo Clinic in 1997. His research contributions were recognized by induction to the National Academy of Kinesiology as an International Fellow and as a Fellow of the American College of Sports Medicine. Professor Gabriel is a past president of the International Society for Electrophysiology and Kinesiology and is co-author of the textbook "Essentials of Electromyography." He has secured 1.17 M in external funding from NSERC and CHIR. His research areas include mathematical modelling of the surface EMG signal and signal processing methods related to motor unit firing patterns. The ultimate goal of his research program is to understand the neural control of muscle force.

EVENT SCHEDULE

Tuesday May 9, 2023

EXP 1689
Expansion Building (EXP)

Time	***Session Description***
5:00 - 6:00 PM	Registration & Poster Setup
6:00 - 6:15 PM	Welcome & Opening Remarks
6:15 - 7:15 PM	Keynote Talk
7:15 - 7:50 PM	Pizza Dinner/Reception
7:50 - 8:50 PM	Poster Session A
9:00 PM	Student-Led Social

Wednesday May 10, 2023

Main Hall
Federation Hall (FED)

Time	***Session Description***
7:30 - 8:30 AM	Continental Breakfast & Registration
8:30 - 9:40 AM	Oral Session 1
9:40 - 9:50 AM	Break
9:50 - 11:00 AM	Oral Session 2
11:00 - 11:15 AM	Coffee Break
11:15 - 12:25 PM	Oral Session 3
12:25 - 1:30 PM	Lunch
1:30 - 2:40 PM	Oral Session 4
2:40 - 2:50 PM	Break
2:50 - 4:00 PM	Oral Session 5
4:00 - 6:30 PM	Lab Tours - B.C. Matthews Hall (BMH)

Time	*Session Description*
	Poster Setup Free/Meeting Time
6:30 - 8:00 PM	Dinner
8:00 - 9:00 PM	Poster Session B
9:00 PM	Trivia Challenge Extravaganza 2020-2023 and Social

Thursday May 11, 2023

Main Hall
Federation Hall (FED)

Time	*Session Description*
8:00 - 9:00 AM	Continental Breakfast & Registration
9:00 - 10:10 AM	Oral Session 6
10:10 - 10:30 AM	Coffee Break
10:30 - 11:40 AM	Oral Session 7
11:40 - 11:50 AM	Closing Remarks
12:00 PM	Faculty Future Planning Meeting

Podium Session 1

Wed May 10

8:30A-9:40A

CHAIRS & AFFILIATIONS

Lia Tennant - University of Waterloo & Thomas Hoshizaki - University of Waterloo

8:30-8:40	Carson Brewer McMaster University	Estimation Of Injury Limits At Vulnerable Impact Locations Along The Forearm Via THUMS V6.1 Finite Element Model
8:40-8:50	Brye McMorran University of Guelph	Vestibular Influence On Compensatory Stepping
8:50-9:00	Blake Miller University of Ottawa	Quadriceps Activation Of Female Adolescents During Isokinetic Testing Pre And Post Acl Surgery
9:00-9:10	Sophia Ngan University of Waterloo	Smoothed Particle Hydrodynamics Implementation To Improve Fracture Response Of A Vertebra Under Compression
9:10-9:20	Joshua Taylor University of Toronto	Markerless Motion Capture Validation With A Knee Brace
9:20-9:30	Chimerem Amiaka Brock University	The Effects Of Vibration On Postural Responses
9:30-9:40	Daphne Ho University of Waterloo	Low Back Loading During PSW Tasks

ESTIMATION OF INJURY LIMITS AT VULNERABLE IMPACT LOCATIONS ALONG THE FOREARM VIA THUMS V6.1 FINITE ELEMENT MODEL

Carson Brewer[1], Aryen Shakib[2], Julia E. de Lange[2] and Cheryl E. Quenneville[1,2]
[1] Department of Mechanical Engineering, McMaster University, Hamilton, ON, Canada.
[2] School of Biomedical Engineering, McMaster University, Hamilton, ON, Canada.

Introduction: Air bag deployment during automotive collisions is a significant potential source for injury to the upper extremity of a driver. Previous work has determined fracture limits of the forearm in response to air bag deployment at two locations along the forearm (1/3 of length from distal end, and midshaft), based on the standard '10 and 2' driving position. With the growth of autonomous vehicles, drivers may use unpredictable hand locations, potentially leaving the upper extremity vulnerable to blunt impacts at alternate sites not previously considered. Vulnerable locations along the forearm must be identified to ensure appropriate injury limits are used in autonomous vehicle safety testing. Finite element (FE) modelling is a valuable tool with which to explore this question through simulation of impacts on a human body model. The purpose of this study was to characterize the effect of dynamic impact testing along the length of the human forearm.

Methods: The left arm of the THUMS V6.1 AM50 human body FE model (Toyota Central R&D Labs, Inc., Nagakute, Japan) was isolated at the humeral head. Validation of the model was performed by recreating the impactor size, location, mass, and velocity from a previous 3-point bending forearm study [1]. The peak force and bending moment were compared to the experimentally-obtained data to determine accuracy of model. Subsequently, impact testing along the forearm was simulated by moving the impactor in 2.54 cm (1 in) increments from the distal to proximal ends of the forearm (**Figure 1)**. Fracture force was identified from the force-strain curve of both the radius and ulna at a critical strain level (1.17%, from the literature). The most vulnerable locations along the forearm were identified as those with the lowest force to fracture.

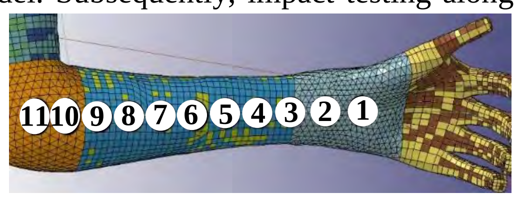

Figure 1: Impact locations.

Results and Discussion: The THUMS upper extremity accurately reflected the previous experimental tests, with the FE model fracture force (at midpoint, between 6-7) of 2391N being within 1% of the previously reported experimental value of 2368N [1]. Impacting of the forearm at alternate locations showed that fracture force changed along the forearm, with the lowest forces (and correspondingly most vulnerable locations) being 1 and 4-7 (closest to wrist and 1/2 to 1/3 distal region) (**Table 1)**. The proximal end (11) was next weakest, likely due to the high proportion of cancellous bone in this region. Conformation of the injury limits at these locations through cadaveric experimental testing will ensure autonomous vehicle safety systems are effective in minimizing injury from a variety of upper extremity impacts.

Table 1: Summary of estimated fracture forces at the forearm locations outlined in Figure 1

Location	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Force (N)	2725.9	3412.3	4297.4	4000.2	2490.9	2265.8	1929.0	2118.0	4902.4	3069.6	2123.9

References:

VESTIBULAR INPUT MODULATES STEPPING BALANCE REACTIONS EARLY IN THE PRE-STEP PHASE THROUGH TO POST-RECOVERY

Brye McMorran[1], Leah Bent[1], John Zettel[1]
[1]Human Health and Nutritional Sciences, University of Guelph, Guelph, ON.

Introduction: Compensatory stepping reactions to recover balance are frequently performed, however the role of sensory feedback in regulating these responses are not well studied [1,2]. Specifically, it is unknown whether vestibular input influences compensatory stepping. Galvanic vestibular stimulation (GVS) applied during non-stepping balance reactions affects a re-establishment of equilibrium after recovery but not the sway reaction itself [2], suggesting vestibular input may not affect compensatory steps. The current study assessed whether step responses utilize vestibular input by combining GVS with step-inducing balance perturbations.

Methods: Standing balance was perturbed via large unpredictable anterior-posterior support surface translations, with GVS that induced perception of left (LGVS) or rightward (RGVS) postural motion or no stimulation (NoGVS). Steps responses were quantified by pre-step anticipatory postural adjustment (APA), whole-body center of mass (COM) motion, and margins of stability (MOS: COM motion relative to base of support).

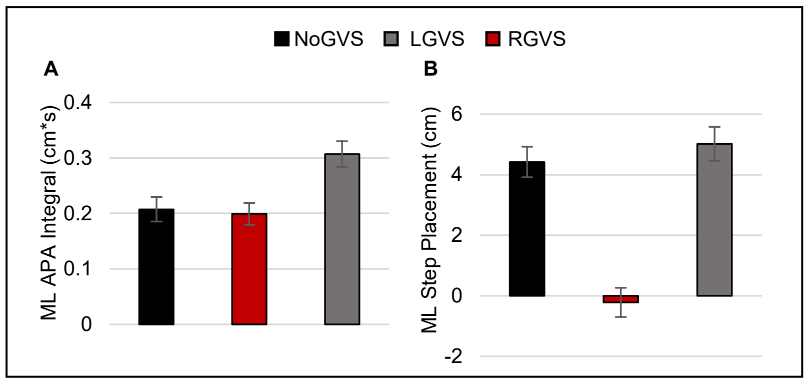

Figure 1: Mediolateral (ML) APA integral (cm^2s) (A) and ML step placement (cm) (B) for each vestibular condition.

Results: GVS affected all phases of the step response, and these vestibular-evoked adaptations were not simple directional responses but differed depending on the GVS direction and phase of the response. RGVS evoked a leftward postural shift (APA) prior to the step (p's <0.007), driving the COM motion (p's <0.01) leftwards at foot-off to create a larger rightward MOS (p's <0.03); however no change in step-width occurred. Conversely, LGVS caused no difference in the pre-step phase nor MOSs but incorporated a leftward step placement (p's <0.0001). At foot-contact, RGVS had a greater leftward COM motion (p's<0.01) with no difference between LGVS and NoGVS. This led to the rightward MOS being largest with RGVS and smallest with LGVS compared to NoGVS (p's <0.0001), and the leftward MOS for RGVS being smaller than LGVS and NoGVS.

Discussion and Conclusions: Results indicate that vestibular input effect compensatory stepping reactions in the early pre-step phase through to post-recovery, and that skewed adjustments were made according to the illusory medial-lateral perturbation induced by GVS to account for stability features of the step. This identifies that vestibular feedback is integrated in accordance with step stability parameters.

References:

[1] W.M et al. (1993). Task constraints on foot movement and the incidence of compensatory stepping following perturbation of upright stance. 616(1). P. 30-38.
[2] T.I. et al. (1995). Effect of Galvanic Vestibular Stimulation on Human Postural Responses During Support Surface Translations. 73 (2); p. 896-901.

QUADRICEPS ACTIVATION OF FEMALE ADOLESCENTS DURING ISOKINETIC TESTING PRE AND POST ACL SURGERY

Blake S. Miller[1], Céline I. Girard[2], Sasha Carsen[3], Daniel L. Benoit[1,2,4]
[1] School of Human Kinetics, University of Ottawa, Ottawa, ON
[2]Department of Mechanical Engineering, University of Ottawa, Ottawa, ON
[3]Children's Hospital of Eastern Ontario, Ottawa, Canada
[4]School of Rehabilitation Sciences, University of Ottawa, Ottawa, ON

Introduction

The anterior cruciate ligament (ACL) is the most injured element of the knee, with adolescent females being at the highest risk for injury [2]. This is further complicated by a lack of research on female-specific biomechanics [3]. Instead, adult literature is often extended to fit the adolescent population with a lack of age- and sex-specific rehabilitation guidelines.

In the adult population, it has been well-established that following an ACL injury and reconstruction, the surrounding musculature, such as the quadriceps, will atrophy, resulting in decreased muscle performance [4]. However, it is unknown if this applies to an adolescent population. Therefore, the purpose of this study was to examine how quadriceps activation changes before, and after an ACL reconstruction, while comparing it to the healthy contralateral limb.

Methods

Nineteen female participants (Age=16.2 ±1.5) with a confirmed ACL-tear (ACLi) performed isometric and isokinetic knee strength testing during two separate visits. Visit 1 occurred before surgery, and visit 2 occurred 8-12-months later, after being cleared by an orthopaedic surgeon.

Participants were outfitted with EMG sensors (Trigno Wireless System, Delsys, USA), placed on the rectus femoris (RF), vastus lateralis (VL) and vastus medialis (VM) of both limbs. Sensors were placed as per the SENIAM guidelines. Maximal voluntary isometric contractions (MVIC) were performed on a dynamometer (System 4 Pro, Biodex Medical Systems, USA) then, following a series of functional tasks, participants performed isokinetic knee flexion and extension from 10 to 100 degrees knee flexion at $90°/s$ with 44 repetitions.

Isometric and isokinetic EMG signals were band passed at 20-450Hz, full-wave rectified, then low-pass filtered using a 4^{th} order zero-lag low-pass Butterworth filter at 6Hz. Isokinetic EMG voltages were then normalized to MVICs. Next, from the isokinetic EMG voltages, the first five repetitions (start) and final five repetitions (finish) were averaged, resulting in starting and final activation values for the RF, VL, and VM. A repeated-measures ANOVA was used to examine start and finish activation differences between limbs of each visit. All statistics were performed using JASP (version 0.14.1).

Results and Discussion

The ACL-injured limb presented higher activation for the RF for both visits (p=0.001), no significant differences were found for VL and VM, however, VL approached significance (Table 1). From Figure 1, the ACL-injured limb presented significantly higher activation for the RF for both visits, when compared to their contralateral limb. For the VL and VM, the ACL-injured limb presented non-significant higher activation for the first and second visit.

Significance

Participant's ACL-injured limb presented higher activation for the RF and VL, when compared to their contralateral limb. This was the case for both visit 1 (pre-surgery) and visit 2 (post ACL surgery). In theory, at visit 2, participants should be ready to return to play, and should not produce significant differences in quads activation, when compared to their healthy

MULTI-PHYSICS SMOOTHED PARTICLE HYDRODYNAMICS-FINITE ELEMENT IMPLEMENTATION TO IMPROVE FORCE-DISPLACEMENT AND FRACTURE RESPONSE OF A VERTEBRA UNDER COMPRESSION

Sophia Ngan[1], Claire Rampersadh[1], Duane Cronin[1]
[1]Department of Mechanical and Mechatronics Engineering, University of Waterloo, Waterloo, ON

Introduction: Human body models (HBMs), such as the Global Human Body Models Consortium (GHBMC) model, provide the opportunity to predict hard tissue injuries such as vertebral fractures [1]. The recent development of an anisotropic material model with young (less than 50 years old) and aged (greater than 70 years old) parameters for the hard tissue of the cervical vertebrae improved fracture prediction at the segment level [2]. However, hard tissue failure was modelled by eroding (deleting) elements from the simulation. This removal of material results in a loss of structural support, which limits post-fracture response prediction under compression loading. This study combined element erosion with a new smoothed particle hydrodynamics (SPH) implementation in the trabecular bone of a finite element (FE) functional spinal unit (FSU) model to reduce material loss and improve post-fracture response.

Methods: A FE FSU model comprising C5 to C7 was extracted from the GHBMC (M50-O v6-0) model and loaded under centric compression as reported in experimental studies [3,4]. SPH was implemented into the trabecular bone by converting a solid Lagrangian element into a SPH element upon erosion. The FE model with and without the SPH implementation was simulated using both young and aged bone material parameters. The force-displacement responses and corresponding energy were compared to the experimental results of age-matched specimens.

Results: The implementation of SPH improved the overall force-displacement response to better agree with the experimental response for both the young (30 and 41 years old) and aged (80 years old) specimens (Figure 1). The implementation of SPH with the young material parameters increased the energy by 47.1%, from 64.9 J to 95.4 J (experiment: 86.4 J). The implementation of SPH with the aged material parameters increased the energy by 14.4%, from 21.1 J to 24.1 J (experiment: 23.8 J).

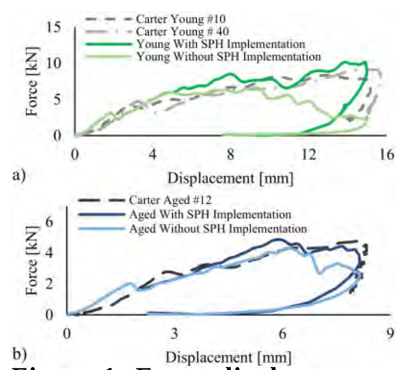

Figure 1: Force-displacement responses of the FE models and the experimental data [4] for the (a) the young and (b) aged specimens.

Discussion and Conclusions: Without the SPH implementation, the loss of material through element erosion in the vertebral body resulted in a reduced post-fracture force. The decrease in post-fracture force was more prominent with the young material parameters due to the more widespread erosion with larger applied displacement. When the SPH implementation was integrated into the trabecular bone, an overall increase in force was observed due to the continuous structural support provided as the solid elements eroded and SPH elements were activated. Thus, the implementation of SPH to model trabecular bone failure improved the post-fracture force-displacement response with both the young and the aged material parameters.

References:

[1] Barker, J. et al. (2017) *Journal of Biomechanical Engineering*. 139 (6); 061009 (11 pages)
[2] Khor, F. et al. (2018) *2018 Injury Biomechanics Symposium*.
[3] Khor, F. et al. (2016) *2016 Injury Biomechanics Symposium*.
[4] Carter, J. et al. (2002) *Stapp Car Crash Journal*. 46; p. 441-459.

VALIDATION OF A MARKERLESS MOTION CAPTURE SYSTEM IN THE PRESENCE OF AN OBSTRUCTIVE KNEE BRACE

Joshua Taylor[1], Ikeade Adeyinka[1], Timothy Burkhart[1]
[1]Faculty of Kinesiology, University of Toronto, Toronto, ON

Introduction: Marker-based (MB) motion capture systems are the current gold-standard of motion capture technology. The primary limitations of MB methods include errors in marker placement and soft-tissue artifact [1, 2]. Accurate marker placement is further challenged when the research requires participants to wear a device that obstructs anatomical landmarks required for marker placement (e.g., wearing a knee brace that restrict access to the femoral condyles). An alternative to MB motion capture is markerless (ML) motion capture technology such as Theia3D (Theia Markerless Inc, Kingston, ON). Theia3D estimates 3-dimensional joint kinematics based on a deep-learning algorithm [4]. While this system has been compared favorably to MB kinematics, its accuracy has not been evaluated when participants are wearing a knee brace. Therefore, the purpose of this study was to validate Theia3D against a MB system in quantifying hip and knee kinematics when participants are wearing a knee brace.

Methods: 14 healthy participants were fitted with an ÖSSUR Rebound Knee Brace (ÖSSUR Canada, British Columbia, Canada) and equipped with a unilateral lower extremity reflective marker set. Three trials each of gait, walking lunges, and squat jumps were performed. An 18-camera Qualisys MB motion capture system (Qualisys AB, Gothenburg, Sweden) was used as the gold-standard and eight synchronized Sony RX0 II cameras (Sony Group corporation, Tokyo, Japan) were used for the ML system. ML data were processed using Theia 3D (Theia markerless, Kingston, ON). Data were exported to Visual3D (C-Motion, Maryland, USA) and frame shifted using cross-correlation to synchronize the two data sets. Task-relevant angles were calculated at the same frames to compare the two systems for each task. Bland-Altman plots were created, root mean squared error (RMSE) values were calculated, and cross correlation values were quantified.

Results: Mean (SD) cross-correlation values for gait, squat jumps, and lunges were 0.98 (0.01), 0.99 (0.01), and 0.98 (0.02), respectively. RMSE values ranged from 4.14º (gait mid-stance knee flexion/extension) to 20.46º (jump landing hip flexion/extension). The RMSE values are comparable to those from previous Theia3D validation research on gait where they found a minimum RMSE of 2.6º (hip abduction/adduction) and a maximum RMSE of 13.2º (knee internal/external rotation). All Bland-Altman plots demonstrated good agreement between Theia3D and Qualisys, with 95% of all differences falling within ±1.96 standard deviations of the mean difference.

Discussion and Conclusions: Overall, the result presented here suggest that the Theia3D ML system generates valid representations of 3D knee and hip kinematics compared to a traditional MB system. The errors in this study, compared to previous literature, are likely attributable to the MB system's difficulty tracking semi-occluded markers from the knee brace. Therefore, when participants are required to wear a knee brace, the use of ML motion capture is justified as it addresses the limitations presented by traditional MB motion capture.

References:
[1] Della Croce D et al. (2005). Gait & Posture 21(2); p. 226–237.
[2] Dumas R et al. (2013). Journal of Biomechanics 47 (2); p. 476–481.
[3] Kanko RM et al. (2021). Journal of Biomechanics 121; p. 110422
[4] Kanko RM et al. (2021). Journal of Biomechanics 127; p. 110665

THE EFFECT OF VIBRATION ON POSTURAL RESPONSES TO AN UNEXPECTED LOSS OF BALANCE

Chimerem Amiaka[1], Dan Anzovino[1], Craig Tokuno[1]
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Introduction: Various methods to improve balance control and reduce fall risk have been explored. For example, vibratory noise input applied to the foot sole has been shown to improve static balance control in various populations (e.g., younger adults, older adults, adults with neuropathy, etc.) via improved sensory perception [1]. However, little research has examined if and how vibratory noise input affects reactive balance control. Since falls typically occur when one is unable to quickly recover their balance when perturbed, there is a need to examine whether the benefits of vibratory noise input extend to reactive balance control. Therefore, the purpose of this study was to determine whether vibratory noise input applied to the plantar surface of the feet affects postural responses following an unexpected surface translation.

Methods: Eighteen young adults experienced 28 surface translation trials. For all trials, participants stood barefoot on a moveable platform, while blindfolded and wearing headphones. Three vibrating elements (3 cm wide x 0.79 cm tall electromagnetic tactors) were placed directly underneath each foot, with a tactor at the first metatarsal, fifth metatarsal and the heel. For each trial, participants were instructed to recover their balance without stepping in response to an unexpected surface translation in either the forward or backward direction. For half of the trials, non-filtered noise signals, set at an amplitude of 90% of each participant’s sensory threshold, were passed through the vibrating elements and remained on for the duration the trial. Vibration was not applied for the remaining trials. Participants were unaware of which trials involved vibratory input and the direction of the upcoming translation. Reactive balance control was quantified through various kinematic and electromyography (EMG) measures.

Results: Results indicated that vibratory noise input did not alter the EMG onsets or amplitudes of the soleus and tibialis anterior muscles. Although the center of mass (COM) displaced about 70-80 mm by 400 ms following surface translation onset, the magnitude of displacement did not change with vibration. Lastly, vibratory noise input did not affect knee and ankle joint angles in either translation direction.

Discussion and Conclusions: Since vibration did not alter the timing or amplitude of postural responses following an unexpected loss of balance, this suggests that the application of vibratory noise input to the foot soles may not be beneficial for younger adults. However, future studies should replicate this study with clinical populations to determine whether vibratory noise input is beneficial for reactive balance control in individuals with worsened balance ability (e.g., older adults).

References:

[1] Cham et al. (2016). Prosthet Orthot Int, 40(6); p.658-667.

QUANTIFYING LOW BACK LOADS DURING PATIENT TRANSFERS COMPLETED BY PERSONAL SUPPORT WORKERS IN A SIMULATED HOME ENVIRONMENT

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Introduction: As our population continues to rapidly age and at-home care becomes increasingly popular, the services provided by personal support workers (PSWs) are in high demand [1]. PSWs frequently perform demanding tasks such as patient transfers and subsequently, are developing high rates of low back-related musculoskeletal injuries [2]. However, majority of research focuses on the quantification of exposures incurred by nurses, and little has been done to understand the nature of PSW work and the associated low back loads within a home environment.

Aim: The aim of this study is to quantify loads at the low back associated with the performance of patient transfers within a simulated home environment.

Methods: PSWs were recruited to complete six transfers with a patient actor. The laboratory was set-up to replicate a patient home environment (Figure 1). Motion capture and hand-force matching were used to capture kinematic and kinetic measures. Peak and cumulative L4/L5 moments will be calculated for each transfer.

Figure 1: Laboratory set-up, replicating a bathroom. Participants must stay within the green markings.

Expected Results: Low back loads for one participant have been calculated (Table 1). It is anticipated that wheelchair to bed transfers will produce the highest peak moment due to the height difference between the two surfaces. Transfers between the bathtub and commode will produce the highest cumulative moment due to the long time length and requirement to lift the patient's legs in/out of the bathtub.

References:

[1] Keefe et al., 2011. Key issues in human resource planning for home support workers in Canada. 40(1); p. 21–8
[2] Alamgir et al., 2007. Work-related injury among direct care occupations in British Columbia, Canada. 64(11); p. 769-75

Table 1: Peak and cumulative moment for all transfer tasks (exemplar results from one participant).

Type of Transfer	Time (s)	Peak Moment (Nm)	Cumulative Moment (Nm*s)
Bed to Wheelchair	69.6	76.89	1035.08
Wheelchair to Bed	47.4	84.53	1379.82
Commode to Wheelchair	29.6	65.69	641.92
Wheelchair to Commode	38.4	72.9	693.95
Commode to Bathtub	41.5	75.65	1234.25
Bathtub to Commode	40	79.44	1468.82

Podium Session 2

Wed May 10

9:50A-11:00A

CHAIRS & AFFILIATIONS

Matheus Correia - University of Waterloo & Calaina Brooke - University of Toronto

9:50-10:00	Sam Vasilounis York University	Trunk Muscle Responses To Dynamic Movements
10:00-10:10	Erinn McCreath-Frangakis Canadian Memorial Chiropractic College	Evaluating Test-Retest Reliability Of The Flexion-Relaxation Ratio Within And Between Days
10:10-10:20	Kyra Wanuch University of Waterloo	Biomechanical Characterization Of Pelvic Floor Contraction Using Novel Ultrasound Imaging
10:20-10:30	Elizabeth Norman Western	A Kinematic Analysis Of Wrist And Carpal Function Utilizing 4D CT Technology: A Novel Perspective
10:30-10:40	Regan Sheppard University of Guelph	Emg Metrics As Predictors Of Subjective Knee Exercise Quality
10:40-10:50	Michael Watson University of Waterloo	Mechanisms Of Endplate Fracture Lesions And Schmorl's Node Injuries During Acute Loading
10:50-11:00	Matthew Ruder McMaster University	Comparisons Between In-Lab And Out-Of-Lab Free-Living Derived Gait Parameters

EFFECT OF AN OVERHEAD FATIGUING TASK ON TRUNK MUSCLE RESPONSES TO DYNAMIC MOVEMENTS

Sam S. Vasilounis[1], Matthew S. Russell[1], Jaclyn N. Chopp-Hurley[1], and Janessa D.M. Drake[1]
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Introduction: Overhead work poses substantial musculoskeletal stress in the upper extremities and trunk due to detrimental postures and sustained loading [1]. The lumbopelvic-hip complex (LPHC) reduces physical demands on the upper extremity's distal segments by controlling adequate energy transfer from the lower extremity through the trunk [2]. This may influence the dynamic control of the LPHC during dynamic tasks since one's capacity to stabilize the trunk heavily influences their capacity to control the lower extremity [2]. The aim of this research was to examine the effect of an overhead drilling task to fatigue on trunk and lower limb kinematic and kinetic responses to dynamic tasks post overhead fatigue.

Methods: 12 healthy, right-handed adults (19-35yr; BMI 22.4 ± 1.7 kg/m^2) were instrumented with Xsens Awinda wireless motion tracker system (Xsens TM Technologies B.V. CA, USA) on the lower limb. Using a Delsys Trigno System (Delsys Inc., Natick, MA), a total of eight surface and two fine-wire intramuscular electrodes were used in quantify trunk and lumbopelvic electromyography (EMG). Further, trunk and right upper limb kinematics using a Vicon® MX system (Vicon Motion Systems Limited, Hauppauge, NY). Participants executed a fatiguing overhead drilling (FOD) task while standing until volitional fatigue [3]. Prior to and following the FOD, participants completed three sets each of a series of dynamic tasks. These tasks included: single leg balance ask (eyes open and eyes closed), single-leg squat (SLS), and single-leg drop landing (SLDL) task [2, 4].

Results: Preliminary results indicate that individuals displayed decreased peak left hip flexion during right SLS task POST-FOD (63.7° ± 4.5) compared to PRE-FOD (100.7° ± 5.8, p = 0.03). Furthermore, after the FOD task participants displayed increased peak centre of pressure displacement in the anterior-posterior axis (Figure 1, 34.1mm ± 5.4 and 55.9mm ± 3.7, p = 0.006) and increased knee varus during right SLDL task compared to prior the FOD task (-11.11° ± 2.2 and 8.3° ± 2.5, p = 0.01).

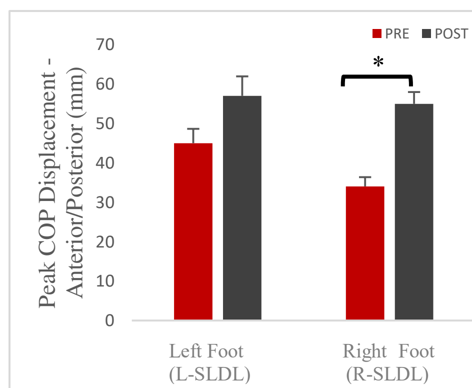

Figure 1: A comparison of peak COP-AP displacement in the left and right foot during the SLDL task pre and post FOD, respectively (*p = 0.006)

Discussion and Conclusions: These initial results suggest there may be a decrease in LPHC dynamic control as displayed through the SLS and SLDL tasks as a result of overhead drilling task to volitional fatigue. Moreover, the difference between limbs in these dynamic tasks could be due to a deficit in unilateral LPHC control. Further examination between these changes in trunk and lower limb kinematics and kinetics are to be determined.

References:

[1] Grive, J. et al. (2008). *Occupational Ergonomics* (8) 53-66. [2] Kibbler, W. et al. (2006). *Sports medicine* (36); 189-98. [3] Sood, D. et al. (2017) *Ergonomics* (10), 1405-1414.

EVALUATING TEST-RETEST RELIABILITY OF THE FLEXION-RELAXATION RATIO WITHIN AND BETWEEN DAYS

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Introduction:

The flexion-relaxation ratio (FRR) has been proposed as a biomarker to address the need for more objective measures of physical function in people with low back pain [1]. Derived from electromyographic (EMG) signals during forward bending tasks, studies of the FRR have mainly focused on its validity. Reliability and measurement error of the FRR are still unknown and must be assessed before use. This study evaluated the test-retest reliability and measurement error of the FRR.

Methods:

Participants were recruited for two sessions, one week apart. Each participant completed standardized pain-related questionnaires at session one, and numerical ratings of low back pain at both sessions. Kinematics of the lumbar spine were derived from accelerometers (ADXL335, Analog Devices, Norwood, MA, USA) at L1 and S1 spinous processes. EMG data were obtained from the right and left lumbar erector spinae (RLES, LLES) at L3 (Bagnoli-16, Delsys Inc., Boston, MA, USA). Each session comprised of two sets of full forward bending trials with a wash-out period. Linear envelopes were created for the EMG data with a dual pass 2^{nd} order Butterworth filter with a 2.5Hz cut-off frequency. The FRR of the RLES and LLES muscles was determined for each trial $\left(\text{FRR}=\max\left(\text{EMG}_{\text{flexing}}\right)/\text{mean}\left(\text{EMG}_{\text{flexed}}\right)\right)$. Intraclass correlation coefficients ($ICC_{2,1}$) of the RLES and LLES were calculated to assess the within-session and between-session reliabilities. Standard errors of measurement (SEM), and minimal detectable changes (MDC) were also calculated [2].

Results:

Data were collected from 50 participants (26 female, age = 26.0 ± 2.7 years, height = 1.73 ± 0.09 m, mass = 73.7 ± 14.7 kg). RLES and LLES FRR group averages were 3.78 ± 2.12 and 4.06 ± 2.65 respectively. Moderate test-retest reliability was observed both within-session ($ICC_{2,1}$ = 0.70 (RLES-Session 1), 0.52 (RLES-Session 2), 0.76 (LLES-Session 1) and 0.58 (LLES-Session 2)) and between-session ($ICC_{2,1}$ = 0.48). Calculated SEMs within-session and between-session were between 1.01-1.89 which equated to MDCs ranging from 75-136% of the mean FRR.

Discussion and Conclusions:

This study is the first to assess the FRR measurement error within and between days of the lumbar erector spinae musculature. The moderate test-retest reliability with MDCs that are comparable to the sample mean calls into question the suggested use of the FRR as a biomarker for the assessment of physical function in individuals with low back pain.

References:

[1] Moissenet F. et al. (2021). A systematic review of movement and muscular activity biomarkers to discriminate non-specific chronic low back pain patients from an asymptomatic population. *Sci Rep* 11(1); p. 5850
[2] Weir JP. (2005). Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res* 19(1); p. 231-240.

BIOMECHANICAL CHARACTERIZATION OF PELVIC FLOOR CONTRACTION USING NOVEL ULTRASOUND IMAGING

Kyra Wanuch[1], Alexandra Blokker[2], Stewart McLachlin[1]
[1]Mechanical and Mechatronics Engineering, University of Waterloo, Waterloo, ON
[2]Cosm Medical Corp., Toronto, ON

Introduction: Pelvic floor disorders (PFD) including pelvic organ prolapse (POP) will affect 50% of women in their lifetime [1]. Pelvic floor muscle strength assessment is a common PFD evaluation, where a patient's voluntary contraction is manually evaluated for strength and control by a clinician. However, this evaluation method is not a quantitative assessment, limiting biomechanical understanding of pelvic floor contraction. To address this challenge, this research aims to characterize pelvic floor contraction biomechanics using novel ultrasound (US) imaging on women successfully using a removable prosthetic pessary device for POP.

Methods: Forty-five patients (age 66±12) were recruited. A modified urodynamic system was used to fill an ultrathin bag in the vagina with water while a novel device covered the introitus to prevent bag dislodge and provide an imaging window. The bag was filled to distend the vagina to a fullness sensation. 25mL was then removed to allow the patient to perform a contraction which was captured in a 2D transintroital US video. The US were segmented in 3D Slicer and evaluated at 1cm intervals. Several measurement changes from these interval points were analyzed during voluntary contraction, namely anterior-posterior (A-P) length, inferior-superior (I-S) bag length, bag area in the sagittal plane. All patients were then averaged using ARCGen [2] in MATLAB.

Results: US with poor visibility or no visible contraction were removed resulting in 19 US videos that successfully segmented the bag area on the 2D video (Fig.1A). The average change in A-P length (Fig.1B) and bag area (Fig.1C) over time are shown below.

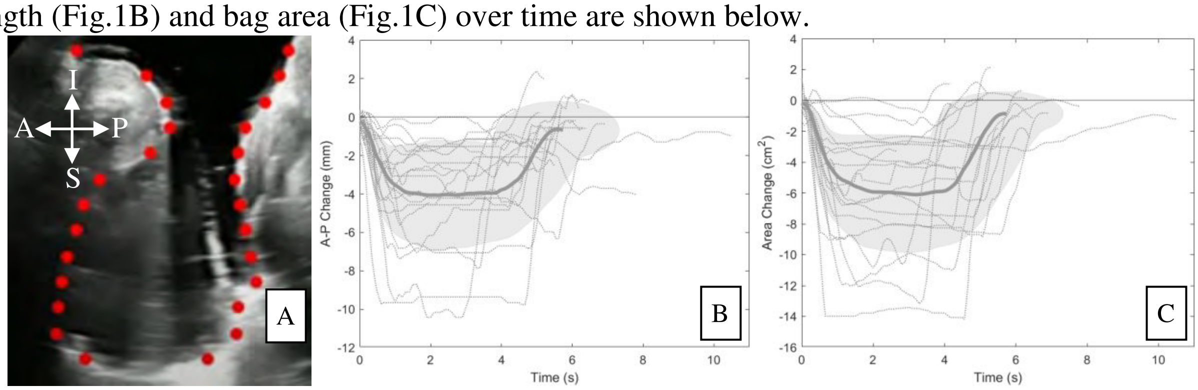

Figure 1: (A) Discrete points segmented on the bag from US, (B) minimum width A-P change, (C) sagittal plane bag area. The ARCGen patient average is the solid line with shaded response corridors, while dotted lines represent individual patients' data.

Discussion and Conclusions: This is the first time dynamic contraction of the pelvic floor has been quantitatively assessed. Characterization of pelvic floor action during contraction in US video measurements could allow clear assessment of pelvic floor disorder related differences and impairments; however, further investigation is needed. This could inform our understanding of impaired pelvic floor biomechanics which can inform treatment options, such as pessary use or surgical intervention, for women suffering from PFDs.

References:

[1] Sung V and Hampton B. (2009). Obstet Gynecol Clin North Am. 36(3); p. 421-43.

[2] Hartlen D and Cronin D (2022), Frontiers in Bioeng and Biotech. 10; p. 843148.

A kinematic analysis of wrist and carpal function utilizing 4D CT technology: A novel perspective

Norman, E, PhD Candidate., Mistry, M, MD., Lalone, E, PhD., Suh, N, MD.

Background: Carpal kinematics have been studied over many years developing numerous theories for how the carpal bone articulate with one another, however none of these theories have been universally accepted[1] . Previous studies that examine complete carpal kinematics have been accomplished through static imaging techniques and in vitro analyzes which have inherent limitations to describe in vivo dynamic motion. Four-dimensional computed tomography is an emerging technology that can examine in vivo dynamic motion, its efficacy for use in the wrist has been established. Therefore, an examination of complete carpal kinematics using this new technology is warranted to provide a new perspective on carpal kinematics. Thus, the objective of this study is to examine carpal kinematics throughout flexion/extension motion of the wrist utilizing 4D CT.

Methods: Twenty healthy participants were recruited and scanned using four-dimensional computed tomography. These participants completed both a static and kinematic scan where the participants were instructed to complete the flexion and extension motion of the wrist joint. The common range of motion between all participants was 40 degrees of extension to 40 degrees of flexion and therefore this range of motion was analyzed. Three dimensional models of both the radius and carpal bones, except for the pisiform, was reconstructed through a semi-automatic segmentation for every 10 degrees of motion in the kinematic scan and were reconstructed in the static scan. The static models were then registered to the position of the kinematic models and transformation matrices obtained. They were then used in our adapted Matlab code to calculate the helical axes and rotations of each bone throughout the motion.

Results: The results show that the distal carpal row, the hamate, capitate, trapezoid, and trapezium move together throughout the motion whereas the scaphoid, triquetrum, and lunate all move independently from one another, Figure 1. These allocations of carpal bones were all significantly different from one another ($p<0.05$).

Summary Points: The allocation of the carpal bones in this study is similar to the groupings within Sandow's central column theory with the exception of the lunate, which rotates separately from the distal carpal row. This study examined dynamic wrist motion and allows for a new perspective on complete intact carpal kinematics.

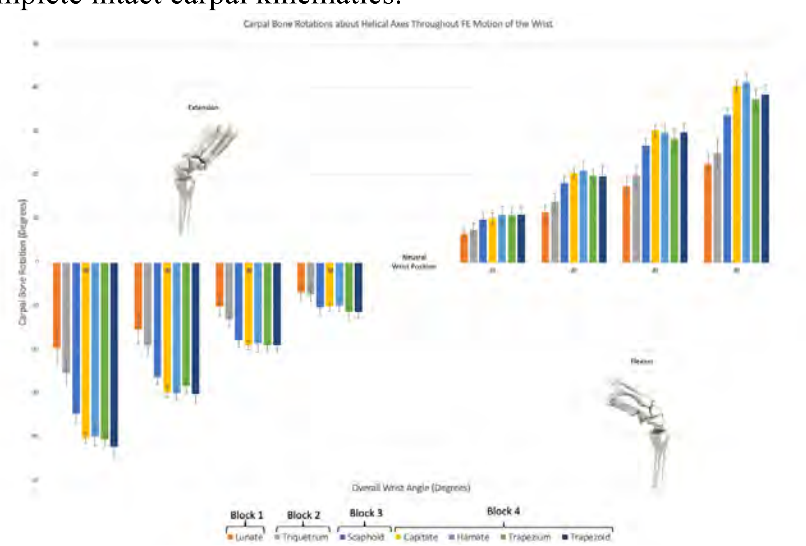

Figure 1: Carpal Bone Rotations about the helical axes throughout Flexion/Extension motion of the wrist

EMG METRICS AS PREDICTORS OF SUBJECTIVE KNEE EXERCISE QUALITY

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[2]Joint Performance Inc., Mississauga, ON

Introduction: Isometric exercises are effective at increasing both muscle mass and strength [1][2]. However, the effect of exercise quality (i.e. how well the exercise is performed) on patient outcomes is not fully understood, partly because it is difficult to quantify exercise quality. This study investigated the relationship between electromyography (EMG) metrics (Mean, Peak, RMS) and subjective visual movement quality scores (MQS) during knee exercises. It was hypothesized that correlations would exist between MQS and (1) participant effort (2) muscle activation metrics in compensatory (non-target) muscles.

Methods: Twelve healthy participants (7M, 5F) with no history of knee pain or surgery performed three exercises: isotonic internal (IR) and external (ER) tibial rotations, and isometric knee extensions (KE) at three distinct effort levels ("high" = 100%, "moderate" = 75%, and "low" = 25%) for five repetitions each. Effort was modulated via real-time feedback from an in-line load cell (LC). Seven surface electromyography (EMG) sensors (Delsys Inc., USA) were placed on muscles of the right leg (tibialis anterior, gastrocnemius medialis, vastus lateralis, vastus medialis, rectus femoris, biceps femoris) and low back (erector spinae) per SENIAM guidelines. EMG and LC data (2000Hz) were collected via Vicon (Vicon Motion Systems Ltd., UK) and exported to MATLAB™ (MathWorks Inc., USA). The middle three repetitions were analyzed for each trial. Processed LC data (low-pass: Butterworth, 1Hz) were normalized to the peak load during each exercise and EMG data (band-pass: Butterworth, 20-300Hz; envelope: Butterworth, 1Hz) were normalized for each muscle to the peak EMG across all trials. A single physiotherapist (PT) provided MQS from synchronized videos, using a 1 (poor) – 10 (perfect) qualitative scale. Linear regression was used to quantify relationships between: i) MQS and instructed effort levels, ii) instructed and achieved (mean peak LC) effort, and iii) MQS versus EMG (Mean, RMS, and mean-peak).

Results: An inverse linear relationship was found between instructed effort level and MQS for Internal (IR, R^2=0.98) and external (ER, R^2=0.97) tibial rotations and knee extensions (KE, R^2=0.75) (Figure 1). Participants achieved the instructed effort levels with 92.63(±4.6), 97.16(±2.5), and 92.14(±0.8) percent accuracy for low, moderate, and max effort levels, respectively. No strong effect was found between MQS and RMS, peak, or average EMG (R^2<0.6), considering all muscles and exercise types.

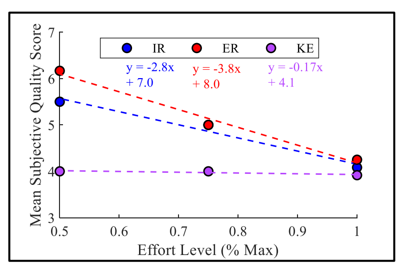

Figure 1: MQS vs. Effort

Discussion and Conclusions: While the EMG outcomes explored in this work were not correlated with subjective MQS, a strong, negative correlation between MQS and instructed effort level for all exercise types suggests that exercise form generally degrades as effort increases. Future work will investigate kinematic data as predictors of MQS, and link quantitative MQS versus patient outcomes.

References:

[1] Balshaw T. et al. (2016). Training-specific functional, neural, and hypertrophic adaptations to explosive- vs. sustained-contraction strength training. J Appl Physiol. 120(11); p1364-1373

[2] Lum D. and Barbosa T.M. (2019). Brief Review: Effects of Isometric Strength Training on Strength and Dynamic Performance. Int J Sports Med. 40(6); p363-375

MECHANISMS OF ENDPLATE FRACTURE LESIONS AND SCHMORL'S NODE INJURIES DURING ACUTE LOADING

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Introduction: The hyaline cartilage endplate is vulnerable to injuries such as Schmorl's nodes and fracture lesions [1,2]. While both injuries are associated with acute compression traumas [3,4], the damage pathways and criteria that separate their incidence is poorly understood. Previous studies have hypothesized an association between trabecular bone fragility and Schmorl's nodes [4]; however, this mechanism remains untested. Furthermore, loading parameters such as compression loading rate can alter the location of failure in spinal units [3]. Therefore, this study evaluated the effect of localized trabecular bone strength deficits and loading rate on ultimate force, loading stiffness, and failure morphology during acute compression exposures.

Methods: Forty-eight porcine spinal units were assigned to one of eight experimental groups that differed by initial condition (control, sham, chemical fragility, structural void) and loading rate (3 kN/s, 9kN/s). Chemical fragility and structural void groups involved a verified 49% reduction in central trabecular bone strength and removal of central trabecular bone, respectively [5]. Acute compression testing was performed with a servo-hydraulic materials testing system that was operated in load control. Force and actuator position were sampled at a rate of 1000 Hz. From the force-displacement data, ultimate force and loading stiffness were calculated. Post-loading dissection was subsequently performed to classify the injury morphologies in accordance with existing criteria [6,7]. Between group differences in ultimate force and loading stiffness were evaluated using a general linear model ($\alpha = 0.05$) and descriptive statistics were used to assess the incidence of injury morphology.

Results: Schmorl's nodes occurred exclusively in chemical fragility (5, 63%) and structural void groups (3, 37%). Within chemical fragility groups, Schmorl's nodes were only observed in specimens exposed to a 9 kN/s loading rate (5, 100%). In contrast, fracture lesions occurred in all FSUs assigned to the control groups (12, 100%) and the majority of those assigned to the sham groups (11, 92%). Interestingly, Schmorl's nodes were more prevalent with a 9 kN/s (6, 75%) loading rate, compared to 3 kN/s (2, 25%).

Discussion and Conclusions: Although localized trabecular strength deficits did not appreciably influence joint properties, an effect on failure morphology was observed. That is, pre-existing strength deficits of the subchondral trabecular bone is a necessary criterion that separates the incidence of Schmorl's nodes and fracture lesions of the end plate. In addition to predisposed mechanical weakness, the exposure of an acute, high impact loading scenario is a determinant of the Schmorl's node's pathogenesis.

References:

[1] Ferguson SJ et al. (2003). *Eur Spine J*. **Suppl 2**; 97-103; [2] Perey O (1957). *Acta Orthop Scand*. **25**; 1-101; [3] Yingling VR et al. (1997). *Clin Biomech*. **12**; 97-103; [4] Fahey V et al. (1976). *Spine*. **23**; 2272-5; [5] Zehr JD et al. (2022). *Clin Biomech*. Submitted. [6] Gallagher et al. (2006). *Clin Biomech*. **21**; 228-34; [7] Wang et al. (2012). *Spine*. **27**; 1432-39.

COMPARISONS BETWEEN IN-LAB AND OUT-OF-LAB FREE-LIVING DERIVED GAIT PARAMETERS

Matthew C. Ruder[1], Monica Malek[2], Kim Madden[3], Anthony Adili[3], Dylan Kobsar[1]
[1]Department of Kinesiology, McMaster, University, Hamilton, ON
[2]Department of Biomedical Engineering, McMaster, University, Hamilton, ON
[3]Department of Surgery, McMaster, University, Hamilton, ON

Introduction: Knee osteoarthritis (OA) is a degenerative disease that results in decreased quality of live. Over time, the changes in bone and surrounding tissues in the knee can require a total knee arthroplasty (TKA) as an end-stage treatment. Gait analysis can inform clinicians with important information as to the progression of knee OA, but lab-based assessments may not fully reflect how the patient moves in the real world. Few studies have directly assessed the relationship between in-lab gait measures against longer-term free-living gait assessments using wearable sensors.

Aim: The aim of this study was to compare gait parameters derived from in-lab to out-of-lab.

Methods: 10 older adults (Range: 50-71 yrs) with moderate-to-severe knee OA were recruited from an orthopedic clinic at surgical decision. Following consent, patients had one wearable inertial sensor (AX6, 100 Hz, Axivity Ltd, Newcastle, UK) on placed on each leg at the anterior-medial aspect of the proximal tibia to be worn for one week and returned. Retroreflective markers were placed on lower body anatomical landmarks for being recorded walking 4-5 times using motion capture (Optitrack, NaturalPoint, Corvallis, OR, USA). Sensor data were processed using a custom Python script identifying walking segments and strides [1][2]. In-lab data were processed using Visual3D pipelines to calculate gait parameters each side. Asymmetry index (ASI) was calculated between mean stride times (ST).

Results: An average of 14.0 strides/patient were analysed from the in-lab gait analysis compared to 6187.2 strides/patient from out-of-lab gait (Table 1). Mean in-lab ST were not significantly less than mean free-living ST (p = 0.17), but mean standard deviation of ST and ASI were significantly greater in free-living ST than in-lab (p=0.006, and p=0.04, respectively).

Discussion and Conclusions: While a limited number of strides collected in-lab are generally consistent, free-living assessment has a much greater number of strides with a greater range of steps collected. The lack of agreement between the in-lab and free-living data could also be due to the OA patient population known to have a high degree of variability due to fluctuation in daily pain that cannot be captured with in-lab systems. Further refinement of free-living collections could lead to more representative patient data to be used in treatment decisions in clinical populations.

References:

[1] Ullrich, et al. (2020). *IEEE J Biomed*. 23(7), 1869-78.
[2] Mariani, et al. (2013). *Gait &Posture*. 37, 229-34.

Table 1: In-lab vs free-living stride time comparisons. * indicates p<0.05.

	Mean Strides/Patient	Mean ST (s)	Mean St. Dev. of ST (s)*	Mean ASI*
In-Lab	14.0	1.18 (0.10)	0.07 (0.03)	2.21 (1.3)
Free-Living	6187.2	1.22 (0.17)	0.44 (0.59)	10.7 (13.5)

Podium Session 3

Wed May 10

11:15A-12:25P

CHAIRS & AFFILIATIONS

Justin Davidson - University of Waterloo & Emma Donnelly - University of Western Ontario

11:15- 11:25	Michael Watterworth Ontario Tech University	Equations For Estimating Upper-Limb Exoskeleton Support
11:25- 11:35	Chris Vellucci Brock University	A Need For Speed: Objectively Identifying Kinematic Strategies Associated With Faster Sprint Velocities
11:35- 11:45	Denise Balogh Nipissing University	Carpal Tunnel Dynamics During Pinch Gripping
11:45- 11:55	Tanvi Seeburrun University of Waterloo	Measuring Volunteer Head Kinematics Using Instrumented Mouthguards
11:55- 12:05	Matthew Russell York University	Shoulder Muscle Co-Activation Changes Following Fatigue
12:05- 12:15	Wayne Allison University of Western Ontario	Evaluating The Neuroanatomy Affected In Concussion
12:15- 12:25	Erika Howe University of Guelph	Foot Loading Impacts Skin Sensitivity

EQUATIONS FOR ESTIMATING UPPER-LIMB EXOSKELETON SUPPORT

Michael W.B. Watterworth[1], Ryuta Dharmaputra[1], Ryan Porto[2], Joel A. Cort[3], Nicholas J. La Delfa[1]
[1]Faculty of Health Sciences, Ontario Tech University, Oshawa, ON
[2]Global Ergonomics Lab, Manufacturing Engineering, General Motors Company, Detroit, MI
[3]Faculty of Human Kinetics, University of Windsor, Windsor, ON

Introduction: Despite their increasing implementation in industry, there is a paucity of specific information regarding the precise torque provided by competing upper-limb exoskeletons throughout their operating range. This makes it difficult to optimize exoskeleton effectiveness based on individual or work task parameters. As such, the dual purposes of this study were to: 1) develop a reliable standardized methodology for measuring passive upper-limb exoskeleton torque; and 2) develop regression equations to estimate the level of support provided by four commercially available exoskeletons throughout their operational ranges and for their various support settings.

Methods: The HUMAC NORM Isokinetic Dynamometer (Computer Sports Medicine Inc., Stoughton, MA, USA) was used to isometrically evaluate the supportive torque provided by four different passive upper-limb exoskeletons (Levitate AIRFRAME V1, SuitX ShoulderX V3, Ottobock Paexo Shoulder V1, and Ekso EVO). Measurements were taken throughout their operational ranges in 10-degree increments, at all possible support levels and activation ranges. Once the cuff was affixed to the dynamometer, the direction of rotation of the exoskeleton and dynamometer arms were placed in parallel, and their axes of rotation were aligned. The measurement procedures were repeated four times to assess between-session reliability. Polynomial regression equations were fitted to each torque profile to predict level of support from arm elevation angle (Figure 1).

Figure 1: Testing setup and predicted exoskeleton torque for all possible combinations of exoskeleton support level and activation range for the SuitX ShoulderX.

Results: Fifty-six of the ICC estimates were in the 'Excellent' range, while the remaining twelve were in the 'Good' range. Confidence intervals indicate the methodology had 'Moderate' to 'Excellent' relative between-session reliability. Mean R^2 of the polynomial regression models was 0.94 across all exoskeleton models and settings.

Discussion and Conclusions: A reliable methodology was developed to measure the specific supportive torque provided by four commercially available passive upper-limb exoskeletons. Based on the worker's shoulder elevation angle, these equations can be used to approximate the effects of upper-limb exoskeleton usage on shoulder moment in static overhead postures. The equations can be

A NEED FOR SPEED: OBJECTIVELY IDENTIFYING KINEMATIC STRATEGIES ASSOCIATED WITH FASTER SPRINT VELOCITIES

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Applied Health Sciences, Brock University, St. Catharines, ON

Introduction: Sprint velocity is a result of an athlete coordinating multiple body segments in a rhythmic fashion to accelerate their body forward. This suggests whole-body intersegmental coordination may be associated with improved sprint velocities. Despite this, many studies have assessed specific sub-regions[1,2] of the body and have selected discrete parameters a-priori. The **purpose** of this study was to leverage wearable sensors and data-driven tools to objectively assess the kinematic and determinants of sprint velocity. This hypothesis-generating study will serve as the basis for future work on the development of an objective athletic performance scoring tool.

Methods: 41 healthy university aged athletes were recruited for this study. Participants were asked to run three maximal 60 m sprints while wearing a 17-sensor IMU motion capture suit (XSENS MTw Awinda, Netherlands). The five strides about the point of peak velocity were, drift corrected, stride segmented, time-normalized, and ensemble averaged before being input into the PCA matrix (40 participants*64 markers*3axes*101 data points). Following the application of PCA to the matrix, PCs that explained >95% of the variance in the dataset were retained and used as inputs into a stepwise multivariate linear regression (p<0.10) to assess relationships with sprint velocity. Multi-component reconstruction was used to reconstruct an upper and lower limit of the functional meaning of the multivariate linear regression models.

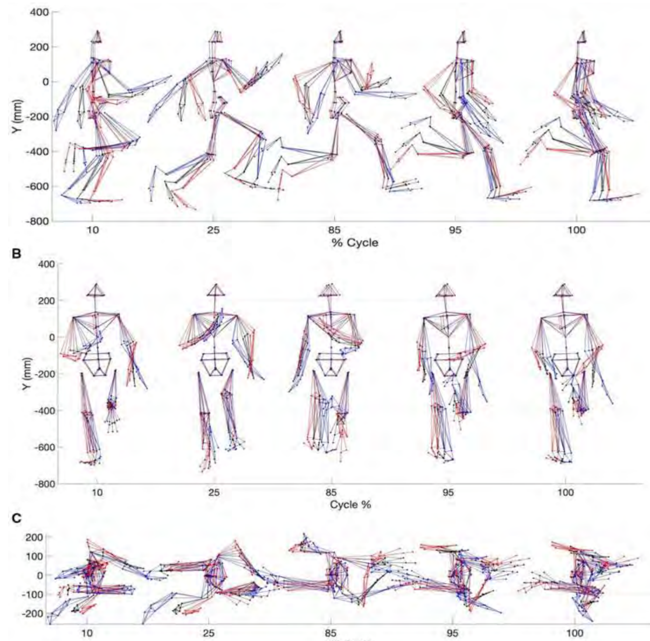

Figure 1: Depiction of the PCs correlated with max sprint velocity. Slow is represented in red, fast is represented in blue

Results: The first 21 PCs were retrained, which explained 95.4% of the cumulative variance in the data set. The stepwise multivariate model displayed an R^2=0.795 with a root mean squared error (RMSE) = 0.351 and a p-value<0.0001. The functional interpretation of the PCs revealed that faster sprint velocity was associated with improved coordination between the upper and lower body, a lowered horizontal head acceleration, a dynamic trunk extension, and various lower limb kinematic differences. The findings of this study suggest that a variety of key time-varying coordinative features are associated with improved sprint velocity (**Figure 1**).

Discussion and Conclusions: This study is amongst the first to identify coordinative differences associated with objective continuous performance outputs. This provides athletes and coaches with objective feedback regarding coordinative features associated with improved sprint velocity. The application of this work can be used in talent identification, performance optimization, and rehabilitation.

CARPAL TUNNEL DYNAMICS IN RESPONSE TO GRIP FORCE LEVEL, REPETITION, AND RATE OF FORCE DEVELOPMENT

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Introduction: Carpal tunnel syndrome (CTS) is a common peripheral neuropathy in workers exposed to occupational risk factors, including repetitive and forceful gripping [1]. Several studies have used ultrasound to investigate the effects of occupational risk factors on carpal tunnel dynamics [2,3]. However, there remains a need to assess the effects of repetitive gripping including varying rates of force development.

Methods: Twelve healthy participants performed a repeated grip task against a load cell (MLP-75, Transducer Techniques, Temecula, CA) while their carpal tunnel was scanned with ultrasound (L15, Clarius, Vancouver, BC). The grip task involved pulp-pinching 3 consecutive times from 0% to 40% maximal voluntary force (MVF), performed at 3 different rates of force development (RFD): 40% MVF/1 s; 2 s; and 5 s. A custom program (LabVIEW, National Instruments, Austin, TX) provided visual feedback of the force matching profiles and collected grip forces at 1000 Hz. Static images were extracted from ultrasound Cineloops at intervals of 10% MVF (from 0% to 40% MVF) as well as .5 s before the start of each ramp and .5 s after 40% MVF was reached. Median nerve width, height, circularity, and displacement were calculated (ImageJ, National Institutes of Health, Bethesda, MD).

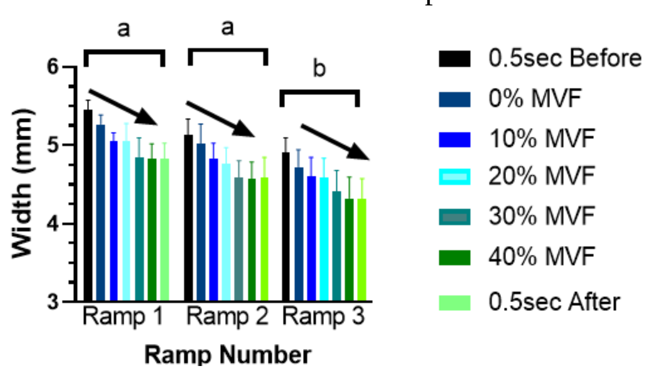

Figure 1. Mean (± SEM) median nerve width as a function of grip force and ramp number. Letters (a,b) indicate significant differences between ramps 1 to 3. Downward arrows indicate a significant decreasing linear trend of width with increasing force magnitude.

Results: Median nerve width decreased as a function of grip force magnitude ($F_{1,11}$=10.85, p=.007) and ramp number ($F_{1,11}$=8.35, p=.015; Figure 1). Median nerve displacement also increased with grip force magnitude from 0% to 40% MVF ($F_{1,11}$=8.62, p=.014). Displacement of the median nerve was greatest during the first ramp with very little displacement in the second and third ramps ($F_{1,11}$=13.89, p=.003). These results indicated an initial re-arrangement of structures within the carpal tunnel upon initiation of a repeated grip task. However, there were no differences between the three RFD.

Discussion and Conclusions: Median nerve displacement and deformation increased with grip force magnitude and repetition (i.e., ramp number). We believe increased localized pressures that develop during the onset of a grip task may lead to sustained median nerve deformation as well as entrapment within the carpal tunnel throughout the duration of a repeated grip task.

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MEASURING VOLUNTEER HEAD KINEMATICS USING INSTRUMENTED MOUTHGUARD AS INPUTS TO DETAILED FINITE ELEMENT HEAD MODEL

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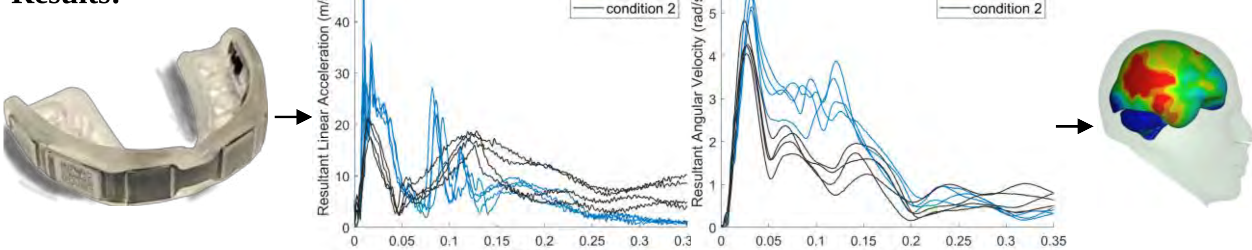
Introduction: Existing head injury metrics such as the Head Injury Criterion (HIC), derived from cadaver and animal experimental testing, provide insights into human tolerance for severe head injuries [1]. However, current metrics are limited in assessing mild traumatic brain injuries (mTBI), recently suggested as a potential occupational risk in the Canadian Armed Forces and associated with repeated acceleration exposures [2]. In this study, the performance and required data processing algorithm for a boil-and-bite instrumented mouthguard (Prevent Biometrics, USA) (Fig. 1A) was assessed for measured head kinematics, which will later be used as input to human body models to assess brain response.

Methods: A volunteer subject (UW REB #44306) was exposed to acceleration events during regular training exercises, including recoil from 0.50 caliber sniper rifles. Four events were recorded under two conditions. In condition 1, the subject assumed their usual posture, with their cheek resting on the buttstock. In condition 2, the subject was instructed to minimize contact between their cheek and the buttstock. The raw angular velocity and linear acceleration data (Fig. 1B), recorded by the mouthguards, were first transformed into the J211 coordinate system then filtered with a 4th order Butterworth lowpass filter to reduce high frequency sensor noise. Finally, a rigid body kinematic transform was applied to determine linear acceleration and angular velocity at center of gravity (CoG) of the head for implementation in a numerical head model (Fig. 1C).

Results:



A B C

Figure 1: (A) Instrumented mouthguard; (B) Resultant linear acceleration and angular velocity (head CoG) measured using mouthguards and post-processed in MATLAB for two test conditions each with 4 repeats; (C) Distribution of brain strains in GHBMC 50th adult male head model as a result of applied head kinematics.

Discussion and Conclusions: The mouthguard successfully detected a change in magnitude of the head kinematics between the two conditions. Condition 1 resulted in higher maximum accelerations, due to increased coupling between the cheek and firearm. The data was successfully applied to a detailed head model and will be used to assess brain response.

References:

INVESTIGATING SHOULDER MUSCLE COACTIVATION RATIO CHANGES FOLLOWING AN OVERHEAD FATIGUE TASK

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Introduction: Subacromial impingement syndrome (SAIS) and rotator cuff tears account for 30-45% of all clinically presenting shoulder conditions [1]. Mechanically, reduction of the subacromial space can result from alterations in shoulder muscle activation and subsequent kinematics, leading to SAIS [2]. The effect of muscle fatigue on kinematics has yielded highly variable outcomes, with differential effects on the subacromial space. It is unclear whether fatigue leads to changes in scapular and rotator cuff muscle co-activity, which may provide insight into kinematic variability [2]. This study investigated fatigue-related changes in shoulder muscle coactivation following an overhead drilling task.

Methods: 18 healthy, right-handed adults (19-35yr; BMI 23.7 ± 3.2 kg/m^2) were instrumented with surface and fine-wire intramuscular electromyography (EMG), and trunk and right upper limb kinematics. Participants used a simulated drill to approximate overhead targets while standing until volitional fatigue [3]. Time-varying normalization permitted EMG amplitude comparisons throughout the fatigue task [4]. Scapular, rotator cuff, and deltoid-rotator cuff coactivation ratios for submaximal 90° abduction and adduction were compared at pre-, mid-, and post-fatigue using one-way ANOVAs.

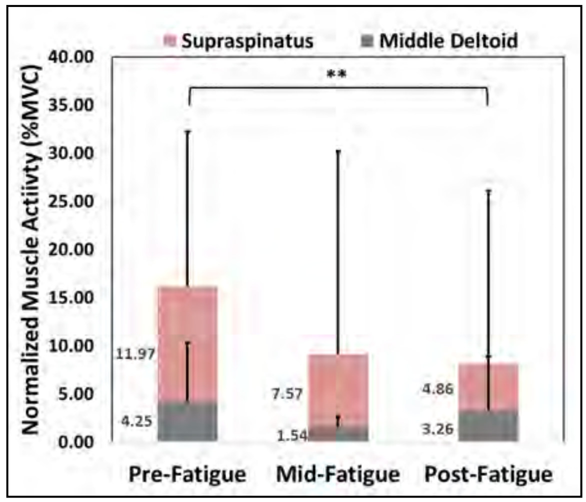

Fig 1: Middle Deltoid-Supraspinatus Coactivation Changes with Fatigue. ** denotes p<0.01

Results: Preliminary results show coactivation changes between middle deltoid and supraspinatus consequent of fatigue from overhead work. Middle deltoid/supraspinatus (MD/SS*100) coactivation ratio ANOVA ($F_{(2,48)}$ = 4.29; p = 0.02) revealed a significant LSD post hoc comparison between the pre-fatigue ($\bar{x}$ = 35.5, sd = 55.1 % MVC) and post-fatigue ($\bar{x}$ = 67.0, sd = 82.6 % MVC) state; p = 0.007 (Fig. 1).

Discussion and Conclusions: Initial results suggest that muscle fatigue consequent of overhead work may produce transient changes to the coactivation ratio between middle deltoid and supraspinatus. Increases in the middle deltoid-supraspinatus activity ratio may increase superior humeral head translation and subsequently imposes risk of SAIS and rotator cuff impingement [2]. Relationships between the changes in muscle co-activation and kinematics are forthcoming.

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[4] McDonald A et al. (2018) J Electromyogr Kinesiol. 39, 58-69.

Evaluating the Neuroanatomy Affected In Concussion

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Objective: Impacts to the body produce impulsive forces on the brain that may result in concussion. This scoping review documented brain regions affected in concussion using neuroimaging modalities. Additionally, the relationships between specific brain regions across multiple imaging methods were investigated.

Methods: Reporting was guided by PRISMA extension for scoping reviews. A literature search was performed using MEDLINE (Ovid), PsycINFO (Ovid), EMBASE, and Web of Science databases to identify studies that performed neuroimaging following a concussion. Searches were performed using key terms relating to concussion, neuroimaging, and anatomical brain regions. Brain regions were documented if they were identified in the methods as regions of interest or reported in results as statistically significant.

Results: Abstracts of 2,131 articles were screened, resulting in full review of 714 studies and content extraction from 103 studies. Across all the studies, 954 brain regions were documented in methods and results, consisting of 146 meaningful brain regions (128 specific and 18 global). Regions of interest predominantly were found in the white matter and frontal lobe regions, accounting for 53.2% of the significant findings. Additionally, 23 of the 146 regions were identified in 10 or more separate studies, independent of imaging methods.

Conclusion: Coordinated evaluation of findings from multiple neuroimaging approaches identified brain regions that are affected in concussion. Some brain regions have not been investigated with the full complement of neuroimaging techniques. The combination of imaging with measured biomechanical forces may be useful in modelling approaches and may warrant further investigation regarding concussion.

THAT DON'T COMPRESSION ME MUCH. YOU'VE GOT THE MOVES, BUT HAVE YOU GOT THE TOUCH? HOW LOADING OUR FEET IMPACTS SKIN SENSITIVITY

Erika Howe[1], Michael Apollinaro[1], Leah Bent[1]
Human Health Nutritional Science, University of Guelph, Guelph, ON

Introduction: Glabrous foot sole skin provides vital sensory feedback about pressure, loading and slips, through the activation of mechanoreceptors [1]. At the same time, loading the foot generates localized ischemia in the skin microvasculature but upon release can be counteracted by a mechanism known as post occlusive reactive hyperemia (PORH) [2]. In hairy skin, PORH is mediated by sensory nerves [2] but remains unclear in the glabrous skin. Widespread ischemia to the entire limb using a cuff has been shown to impair vibration detection thresholds on the heel [3]. It remains unknown if local skin ischemia can generate changes to skin. The current work aims to examine 1) the dose and site-specific changes in sensitivity following skin ischemia 2) the correlations between PORH blood flow and skin sensitivity across the foot sole.

Methods: Capillary flux was recorded using a custom-built-loading device with an in-line laser speckle contrast imager (FLPI-2, Moor Inc). The device applied load to the right foot at 2 magnitudes; 15 or 50% body weight (BW) for 2 durations; 2 or 10 minutes continuously. Each load was followed by a 2-minute PORH recording, repeated 3 times and block randomized. PORH peak and recovery rate was evaluated for skin over the third metatarsal (3MT), medial arch (MA) and heel. On a second test day, after loading, skin sensitivity was assessed using Semmes-Weinstein monofilaments (MF). Perceptual thresholds were determined for each site prior to loading and then after the load was released, was reapplied repeatedly to a metronome for 2 minutes to establish the time course to return to threshold, defined as MF recovery.

Results: Thirteen healthy participants (7 F; 26.5±4.2yrs) were tested. MANOVA main effects were found for site ($F_{2, 288} = 25.09$, $p<0.001$) and duration ($F_{1,143} = 6.12$, $p=0.003$). All blood flow measures for the 3MT and Heel were influenced by loading, while the MA was not. Load Duration was significantly different for recovery rate at the heel, such that flux returned slower in 10 min vs 2 min loading trials (p=0.001). MF recovery by ischemia was most influenced at the heel. Median recovery time at the heel was 0 s after the 2min15% trial, which was significantly shorter than 10min15% (126.7 s, p=0.005) and 10min50% (106.7 s p=0.005), but not the 2min 50% (3.3s, p=0.52). MF recovery was able to significantly predict PORH recovery rate at the heel ($R^2=0.184$, $F_{1,50} = 12.5$, $p<0.001$), such that longer MF recovery time was found to relate to slower PORH recovery rates ($\beta = -0.0019$, $p<0.001$).

Discussion: Findings from this work indicate that microvascular blood flow is essential for sensory feedback in the skin. The duration of ischemia impacts sensitivity regardless of greater PORH flux. PORH is blunted in diabetic populations [4], likely contributing to impaired sensory feedback. Together, this creates a higher risk for foot amputations. Our work provides insight into preliminary mechanisms that contribute to neuropathic ulcerations and highlights the critical need for operative sensory feedback to monitor loads and mitigate ulcer development.

References: [1] Macefield (2005) Clin Exp Physiol [2] Johnson et al (2014) Comp Physiol. [3] Schlee et al (2009) Clin. Neurosci. [4] Petrofsky et al (2009) Med Sci Monit

Podium Session 4

Wed May 10

1:30P-2:40P

CHAIRS & AFFILIATIONS

Jessa Buchman-Pearle - University of Waterloo & Jarrett Norrie - Brock University

1:30-1:40	Olena Klahsen University Ottawa	Body Position Impacts Both Ultrasound Imaging And Intravaginal Dynamometry Measures Of Female Pelvic Floor Muscle Function
1:40-1:50	Jacklyn Kurt University of Waterloo	Effects Of A Passive Upper Extremity Exoskeleton On Shoulder Fatigue During A Simulated Automotive Overhead Work Task
1:50-2:00	Lauren Straatman Western	The Relationship Between Kinematic Joint Contact And Subchondral Bone Mineral Density
2:00-2:10	Anil Palanisamy McMaster University	Association Of On-Court Impact Load With Rating Of Percived Exertion In Basketball
2:10-2:20	Benjamin Kissack University of Guelph	Visual Cue Complexity On Foot Placement Accuracy In A Targeted Stepping Task
2:20-2:30	Alyssa Tondat University of Waterloo	Soft Tissue Thickness And Composition Surrounding The Proximal Femur
2:30-2:40	Noah Chow Wilfrid Laurier University	Examining Adjacent Disc Disease

BODY POSITION IMPACTS BOTH ULTRASOUND IMAGING AND INTRAVAGINAL DYNAMOMETRY MEASURES OF FEMALE PELVIC FLOOR MUSCLE FUNCTION

Olena Klahsen[1], Catriona S. Czyrnyj[2], Kaylee C.L. Brooks[3], Megan Vendermolen[2], Linda McLean[3]
[1]School of Human Kinetics, University of Ottawa, Ottawa, ON
[2]School of Mechanical Engineering, University of Ottawa, Ottawa, ON
[3]School of Rehabilitation, University of Ottawa, Ottawa, ON

Introduction: There is disagreement in the literature regarding the impact of body position on measurements of pelvic floor muscle (PFM) function, with studies showing greater [1], smaller [2] and no difference [3] in vaginal closure force when supine and standing positions are compared. The aim of this study was to evaluate the impact of body position on PFM function when assessed through two-dimensional (2-D) ultrasound imaging (USI) and intravaginal dynamometry (IVD).

Methods: This was a retrospective analysis of data acquired for a cross-sectional, observational study [4]. Female participants were recruited from the local community. Three rest trials and 3 maximum voluntary contractions (MVCs) were performed while vaginal closure force was measured using a custom IVD (anterior-posterior (AP) diameter = 35mm) in both supine and standing positions. 2-D transperineal USI was then used to acquire images of pelvic morphology in the mid-sagittal plane throughout 3 MVCs. IVD outcomes included: baseline, absolute and relative peak forces, as well as rate of force development. USI videos were processed to identify the levator plate length (LPL) and bladder neck height (BNH) at rest and at peak MVC. Data were tested for normality, and the effect of body position was analyzed using paired *t*-tests or Wilcoxon Signed-Rank tests as appropriate.

Results: Twenty-six females (age: 42 ± 2 years, height: 1.66 ± 0.01 m, weight: 70.40 ± 2.38 kg, 22 parous) participated. IVD baseline force was higher in standing compared to supine (9.04 +/- 0.49 N vs. 10.99 ± 0.56 N, p = 0.004) while relative peak force (7.89 ± 0.61 N vs. 5.32 ± 0.47 N, p = 0.001) and rate of force development (16.19 ± 1.54 N/S vs. 9.96 ± 1.17 N/S, p = 0.001) were lower in standing compared to supine, with no change in absolute peak force. Despite longer LPL (45.10 ± 1.30 vs. 49.26 ± 1.55, p = 0.001) and more caudal BNH at rest (27.91 ± 1.86 mm vs. 20.53 ± 1.46 mm, p = 0.003) and at peak MVC (30.07 ± 2.42 mm vs. 21.36 ± 2.00 mm, p = 0.001), there were no differences in the change in LPL or BNH observed during MVC in supine versus standing.

Discussion and Conclusions: Greater baseline force in standing is consistent with prior studies [1,2,3] and may be the result of increased activation of the PFMs and/or increased loading of the dynamometer arms based on the weight of the abdominal contents. The lower relative forces and BNH in standing suggest that the PFMs may have a reduced ability to generate closure force and support the pelvic organs in this position. These findings are consistent with observations that symptoms of pelvic floor disorders are normally worse in upright positions.

References:

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[3] Bø & Finckenhagen (2003) Acta Obstet. Gynecol. Scand. 82; p. 1120-1124.
[4] Czyrnyj et al (2020) Neurourol. Urodyn. 39; 1717-1731.

EFFECTS OF A PASSIVE UPPER EXTREMITY EXOSKELETON ON SHOULDER FATIGUE DURING A SIMULATED AUTOMOTIVE OVERHEAD WORK TASK

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[1]Department of Health, University of Waterloo, Waterloo, ON
[2]Department of Systems Design Engineering, University of Waterloo, Waterloo, ON

Introduction: Exoskeletons have been growing in popularity in recent years [1]. The muscular response to exoskeletons has mostly focused on the superficial anterior and middle deltoid, and upper trapezius [2], however less is known for in shoulder stabilizers like the rotator. Superior humeral head translation followed rotator cuff fatigue in previous research [3], and differential fatigue of the rotator cuff and shoulder elevators represents a potential mechanism [4]. Superior humeral head translation decreases the subacromial space dimensions [5], which may cause subacromial impingement and supraspinatus tendon degradation over time.

Methods: Ten males without history of shoulder injury in the last year participated. Surface electromyography (sEMG) was measured from 5 muscles bilaterally, including the anterior and middle deltoid, upper trapezius, supraspinatus, and infraspinatus. sEMG was sampled using a wireless Noraxon Telemyo 2400 G2 unit (Noraxon 2 USA Inc., Arizona, USA) at a rate of 1500Hz. Participants completed a 2-hour overhead work protocol, consisting of a simulated overhead weld inspection task on an automotive car underbody. Every ten minutes participants completed an EMG reference task, where they held an anthropometrically scaled weighted bottle at 10-15% of the participant's maximum strength for 5 seconds while recording sEMG. From these reference tasks Mean Power Frequency (MPF) was calculated as a measure of local muscle fatigue and normalized to the baseline measure taken at the start of the 2-hour protocol. Two-way one-tailed repeated measures ANOVA's were completed with a p-value of <0.05 indicating significance.

Results: Significant main effects of exoskeleton occurred bilaterally for the supraspinatus and upper trapezius, and the left anterior and middle deltoid. Significant main effects of time existed for bilateral upper trapezius and supraspinatus, and the left infraspinatus (Table 1).

Table 1: Summary of Probabilities (>F values) for ANOVA results for the main effects of exoskeleton and time on normalized Mean Power Frequency (nMPF).

Muscle	RUtrap	RSupra	RAdelt	RMdelt	RInfra	LUtrap	LSupra	LAdelt	LMdelt	LInfra
Exo	**<0.01***	**<0.01***	0.05	0.34	0.74	**<0.01***	**<0.01***	**0.02***	**<0.01***	0.18
Time	**<0.01***	**0.02***	0.20	0.18	0.33	**<0.01***	**<0.01***	0.72	0.25	**0.02***

Discussion and Conclusions: The use of a passive upper extremity exoskeleton reduced local muscle fatigue indicators for the supraspinatus and upper trapezius during a simulated automotive work task over time. This indicates that passive exoskeleton use may reduce the effects of fatigue experienced in both shoulder stabilizers (supraspinatus) and elevators (upper trapezius) during overhead work.

References:

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THE RELATIONSHIP BETWEEN KINEMATIC JOINT CONTACT AND SUBCHONDRAL BONE MINERAL DENSITY

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[2]Mechanical and Materials Engineering, Western University, London, ON
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[4]School of Physical Therapy, Western University, London, ON
[5]Department of Orthopedics, Emory University, Atlanta, GA

Introduction: Wolff's law indicates that bone tissue is influenced by its mechanical environment and adapts in response to the mechanical load that acts on it.[1] Studies analyzing bone adaptation in weight-bearing joints support this law. We wish to study Wolff's law in the wrist, a non-weight bearing joint. Our primary objective is to evaluate the correlation between kinematic joint contact area (JCa) and subchondral volumetric bone mineral density (vBMD), as it relates to depth from the subchondral surface. Our secondary objective is to determine the amount of variance in subchondral vBMD that can be explained by kinematic joint contact.

Methods: We recruited 20 healthy participants, all of which underwent a series of CT scans of their wrist; a static CT scan accompanied by a calibration phantom to obtain measures of vBMD in 3 normalized depths; 0 – 2.5, 2.5 – 5, and 5 – 7.5 mm, and a four-dimensional CT scan (4DCT) where the participant performed maximum wrist extension to maximum flexion. We analyzed vBMD and JCa in the radiolunate (RL) and radioscaphoid (RS) joints separately. For objective one, several Pearson product-moment correlation coefficients were calculated where vBMD was the dependent variable, and kinematic JCa throughout every 10 degrees of motion were the independent variables. Independent variables that were statistically significantly associated with vBMD were assessed using a regression model. The independent variables were entered into the model in steps; (1) significant correlations, (2) sex, and (3) age.

Figure 1: Visual representation of subchondral vBMD normalized layers, beneath the RS and RL joints.

Results: Significant correlations between vBMD and kinematic JCa were demonstrated in the middle (2.5 to 5mm) and deep (5 to 7.5mm) layers of subchondral bone, however there were no significant correlations in the superficial layer (0 to 2.5mm). The regression analysis demonstrated that 51% of the variance in vBMD in region 2 of the RS can be explained by the kinematic JCa and the sex of the participant. In the RS region 3, 40% of the variance can be explained by kinematic JCa and the sex of the participant.

Discussion: We demonstrated significant relationships between kinematic JCa and subchondral vBMD, indicating that Wolff's law is robust in non-weight bearing joints. This relationship is paramount to better understanding joint remodeling following injury, early osteoarthritic signs in the joint, and the influence of vBMD and JCa adaptations on pain.

References:

[1] Brand, R. et al. (2010). Biographical sketch: Julius Wolff, 1836-1902

ASSOCIATION OF ON-COURT IMPACT LOAD WITH RATING OF PERCIVED EXERTION IN BASKETBALL

Anil Palanisamy[1], Josh A.J. Keogh[1], Stevan Japundzic[1], Bahman Bahrami[1], Dylan Kobsar[1]
[1]Kinesiology, McMaster University, Hamilton, ON

Introduction: Monitoring training load in athlete is an essential practice to optimize training response, while assessing the subsequent fatigue to minimize injury risk (1). Training load can be assessed with metrics of internal load (i.e., psychophysiological response to training) such as ratings of perceived exertion questionnaires (RPE) (1,2) and a metric of external load (i.e., physical work completed) such as distance ran or repetitions (1).Our purpose was to (i) examine the association between wearable sensor-derived external load and ratings of perceived exertion (RPE) during on-court practices in men's basketball, and (ii) compare wearable sensor-derived loading between practices and games.

Methods: Eleven male basketball players, free from musculoskeletal injury, on the McMaster University Men's Basketball team participated in the study. Players were fitted with bilateral inertial measurement units (iMeasureU, Vicon) at the ankle to measure resultant acceleration impacts during 11 practices and 5 games over a 3-week period. Two primary variables were obtained from the sensors relating to (i) total impact load (number of steps x resultant acceleration of impact) and (ii) average intensity (average impact intensity from all recorded steps). Additionally, the Borg-10 RPE questionnaire was collected immediately after each practice and used to quantify RPE and sRPE (RPE x practice time). The association between the sensor and self-reported data were quantified using Pearson correlation coefficients. Additionally, sensor variables from practice were compared to those obtained in games using non-parametric paired t-test.

Results: A low and moderate correlation was observed between total impact load and RPE ($r = 0.11$, $p = 0.04$) and sRPE ($r = 0.45$, $p < 0.001$), respectively, for practices. Alternatively, no significant correlation was observed between average intensity and RPE ($r = 0.07$, $p = 0.55$) or sRPE ($r = 0.11$, $p = 0.35$). In comparing games to practices, games were found to display a greater average intensity compared to practices (19.6±2.1g vs. 11.6±2.1g; p=0.004). Although most players had lower total impact load in games vs. practice (66k±29k-g vs. 73k±8k-g vs.; p=0.42), this was not significant given the high amount of variability and limited sample size for in-game data (e.g., n=6 athletes with in-game sensors).

Conclusion: Our results suggest that loading metrics from wearable inertial sensors display low to moderate correlations with practice RPE. We found games to show higher average intensities but may have lower total load on players. Initial findings suggest wearable sensors can provide unique insights into practice and competition load that may not fully captured in RPE alone.

References:
[1] Bourdon, P. C. et al. (2017). Monitoring Athlete Training Loads: Consensus Statement. *International Journal of Sports Physiology and Performance, 12* (s2), S2-161
[2] Haddad. et al. (2017). Session-RPE Method for Training Load Monitoring: Validity, Ecological Usefulness, and Influencing Factors. Frontiers in Neuroscience, 11.

EXPLORING THE EFFECTS OF VISUAL CUE COMPLEXITY ON FOOT PLACEMENT ACCURACY IN A TARGETED STEPPING TASK

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Introduction: Locomotion requires some degree of cognitive demand and the involvement of executive functions including inhibition, updating, and task switching [1]. When task demands change, the visual system may receive advance input about obstacles in our environment (e.g. proximity, shape, possibility of threat) and this sensory information can then be used to adjust ongoing locomotor patterns [2]. We know that switching between two tasks requires a higher-level cognitive demand and can be an important method used to measure the role of executive function for the control of locomotion. This study explored how inhibition, updating, and task switching are used in a visually guided targeted stepping and obstacle avoidance task.

Methods: Participants (N=16) were instrumented with kinematic markers (Optitrak, 100 Hz) and asked to walk along a 7-meter walkway and step ON or OVER a colour-changing obstacle (42 x 20 x 5 cm); obstacle would change from white to red or white to green on approach. Instructions given to the participant, coupled with the light change, would result in a specific response: "Normal" instructions (green=ON, red=OVER); "Switched" instructions (green=OVER, red=ON). Participants were also instructed to "*step as accurately as possible while maintaining normal walking speed*". Accuracy was calculated as distance from foot center of mass (CoM) to raised obstacle center (ON trials) or ground level landing area (OVER trials). A weighted COM (trunk+pelvis) was estimated, and approach velocity was also calculated (start to lead toe crossing lead edge of OBS).

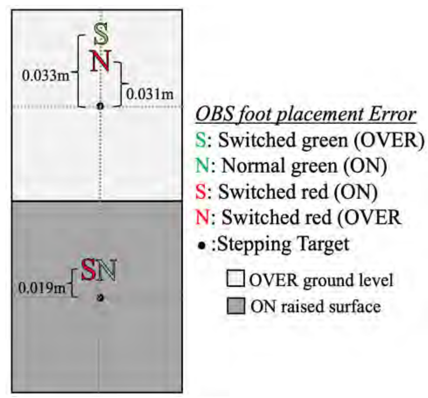

Figure 1. Schematic of mean AP foot placement error (m) for the 4 different task conditions.

Results: Preliminary results indicate that foot placement was most accurate in the medial lateral direction (<1cm error) compared to anterior-posterior (AP). Repeated measures ANOVA revealed an interaction effect (Instruction*Visual cue; $p<0.05$) for AP foot placement; accuracy was highest for "normal green" (ON) and "switched red" (ON) conditions while least accurate in the "switched green" (OVER) condition; see Figure 1. A similar interaction was observed for CoM velocity during obstacle approach ($p<0.05$); velocity was fastest in "normal red" and "switched green" conditions (1.33 m/s) and slower in "switched red" and "normal green" (1.29 m/s) conditions.

Discussion and Conclusions: Preliminary results suggest that motor accuracy decreases as cognitive demand increases. However, this decrease can be minimized by slowing down COM velocity in a targeted stepping task. These findings will help further our understanding about the impact of complex visual cues on targeted stepping and obstacle avoidance tasks.

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DEVELOPMENT OF A PROTOCOL FOR MEASURING SOFT TISSUE THICKNESS AND COMPOSITION SURROUNDING THE PROXIMAL FEMUR

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Introduction: Fall-related hip fractures are a serious injury in older adults. Hip fracture risk is negatively associated with trochanteric soft tissue thickness.[1] While impact loads during sideways falls are influenced by muscle activation, and are distributed throughout the proximal femur region,[2] previous research has neglected the contributions of muscle and adipose tissues to total soft tissue thickness, and has not considered regions surrounding the greater trochanter. Accordingly, this study had two main goals: 1) to assess the reliability of a novel ultrasound protocol for measuring total (TST), muscle (MT), and adipose (AT) soft tissue thickness surrounding the greater trochanter; and 2) to test the hypothesis that measurement location and sex influence TST, MT, and AT.

Methods: 20 young adults (7 male, 13 female) were positioned in a sideways configuration while B mode ultrasound images were taken at 6 cm intervals in a 3 x 4 grid centered about the greater trochanter. Three images were taken at each location and TST, MT, and AT were measured. Intra-rater reliability was assessed using two-way mixed model ICCs, with interpretation as poor, moderate, good, or excellent for ICC's <0.5, 0.5-0.75, 0.75-0.9, and >0.9 respectively. ANOVAs examined the influence of measurement location and sex on thickness for each tissue type.

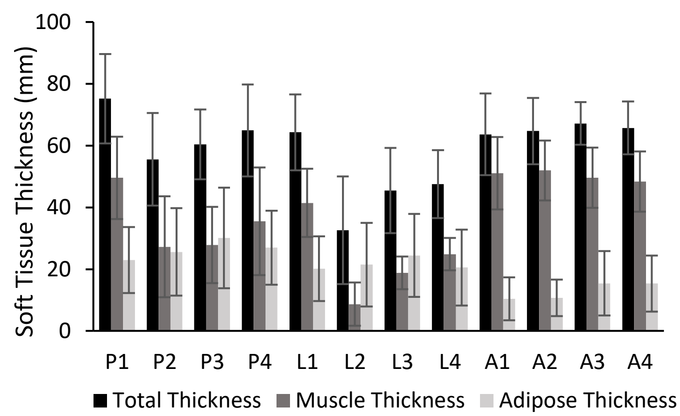

Figure 1: Mean (SD) tissue thickness across measurement location (sexes combined).

Results: For reliability, mean (SD) ICCs were 0.88 (0.14). ICC's were poor for MT at A1; moderate for TST at A1 and P1, and MT at P1; and good or excellent for all remaining tissue types and locations. For thickness magnitudes, significant main effects of location and sex were observed (Figure 1) with males having significantly more muscle (MT) and less adipose (AT) than females, and muscle thickness generally higher in the anterior regions. For TST, a significant interaction between location and sex was observed. Total thickness was higher in the anterior and posterior regions (compared to over the lateral femur (Figure 1)); sex-based differences in TST were smallest over the A3 region.

Discussion and Conclusions: Results highlight that this ultrasound protocol can reliably measure tissue-specific thickness in the proximal femur region. The results also show that TST, MT, and AT vary across locations on the proximal femur and with sex. Accordingly, it may be important to consider areas surrounding the greater trochanter, the differing contributions of MT and AT to TST, and sex when developing models of tissue loading and hip fracture risk (from biomechanical and epidemiology perspectives).

References: [1] Bouxsein et al. (2007). *J Bone Miner Res.* 22(6); 825-831. [2] Pretty et al. (2017). *Ann Biomed Eng.* 45; 2775-2783.

EXAMINING ADJACENT DISC DISEASE: A PORCINE TISSUE APPROACH

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Introduction: One of the primary mechanisms of low back pain can be attributed to the degeneration of the intervertebral disc (IVD) [1]. In cases where degeneration of a IVD is extreme, surgeons may opt to perform a spinal fusion to stabilize the damaged region. While a fusion helps prevent further IVD injury and provides necessary stabilization to the injured area, this procedure has been the center of controversy in regards to its contribution in the development of adjacent disc disease (ADD) [1].

Methods: Forty-four porcine cervical spine C3-5 segments were used for the current study. For each sample, the C4/5 IVD was either injured or left intact and either fused or not fused resulting in the following four conditions: 1) control (no injury/no fusion); 2) injured but not fused; 3) not injured but fused; and 4) injured and fused. Injuries were created by using a 16-gauge needle and piercing through the posterolateral aspect of the spine to the nucleus. Fusion was accomplished by wrapping 18-gauge steel wire around the transverse and spinous processes. Following injury/fusion, each specimen was subjected to a 15-minute preconditioning period under 300 N axial compression followed by a cyclic compression protocol of a 0.5 hertz sinusoidal waveform ranging from 300-1200 N for 2 hours (3600 cycles) (MTS, Eden Prairie, MN) [2]. Post-compression, two annular samples were dissected from the C3/4 IVD (***adjacent*** to the injured/fused level). From these samples, a single annular layer tensile test was conducted to measure the strength of the intRAlamellar matrix and a peel test was conducted to measure the adhesion strength of the intERlamellar matrix.

Results: A significant interaction between injury and fusion (p=0.004) was observed for intRAlamellar matrix strength. Posthoc analyses showed significantly lower single annular layer strength in all experimental conditions compared to control. In contrast, there were no differences ($p>0.05$) found between the conditions for interlamellar matrix adhesion strength.

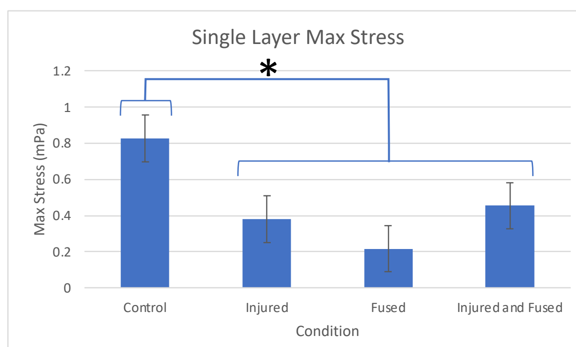

Figure 1: Max Stress (force divided by cross sectional area) of single layer samples for control and each of the experimental groups. Asterisk indicated significance at an alpha level of 0.05.

Discussion and Conclusions: Both fusion and IVD injury appear to negatively impact IVD strength in the adjacent segment. Reduced intRAlamellar matrix strength is associated with disc pathologies, thereby providing a potential mechanism for the occurrence of ADD.

References:

[1] Eck et al. (2002) *Spine*, *27*(22), 2431–34. [2] Zehr et al. (2019) *Ergonomics*, *62*(10), 1339–48.

Podium Session 5

Wed May 10

2:50P-4:00P

CHAIRS & AFFILIATIONS

James Hunter - University of Western Ontario & Pratham Singh - University of Toronto

2:50-3:00	Fergus Lam University of Waterloo	Dependency Of Shoulder Muscle Activation Patterns On Simulated Labral Conditions During Isometric And Functional Tasks
3:00-3:10	Daniel Cousins Brock University	Hand Exoskeleton And Forearm Muscle Activity
3:10-3:20	Stephen Boulanger York University	Subacromial Space Measures Using Ultrasound And MRI
3:20-3:30	Claudia Town University of Windsor	Effect Of Football Shoulder Pads On Reach Distance.
3:30-3:40	Kimberly Peckett University of Waterloo	Frontal Plane Knee Loading During Common Lifting Techniques
3:40-3:50	Marija Bakoc University of Guelph	Quantifying Knee Brace Perturbation Responses During Gait
3:50-4:00	Dominique Cava Western University	The Effect Of Adjusting Frontal Plane Knee Alignment When Scaling Patient-Specific Neuromusculoskeletal Models

DEPENDENCY OF SHOULDER MUSCLE ACTIVATION PATTERNS ON SIMULATED LABRAL CONDITIONS DURING ISOMETRIC AND FUNCTIONAL TASKS

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Introduction: Glenohumeral joint stability depends on a combination of shoulder muscular action and the glenoid labrum. Labral injuries and degenerations can affect glenohumeral joint reaction forces and potentially increase shoulder muscle efforts [1]. However, the relationship between shoulder labral condition and muscle demands remains unclear as the compensatory muscle strategies lacked identification. Targeted analysis was required to determine the activation pattern of each muscle which traditional non-invasive biomechanical physical measurements cannot easily achieve. The purpose of this study was to determine how simulated labral statuses influence shoulder muscle activation patterns using a mathematical biomechanical shoulder model.

Methods: Isometric and functional movement tasks kinematic data were collected using a VICON MX20 passive motion capture system (VICON, Oxford, UK) to provide geometric inputs to the shoulder model using a single male participant. Muscle forces (%MVC) and joint contact forces for the glenohumeral joint were predicted by the Shoulder Loading Analysis Modulus (SLAM) model [2]. Compromised labral conditions were simulated by altering the glenoid stability constraints of the SLAM model.

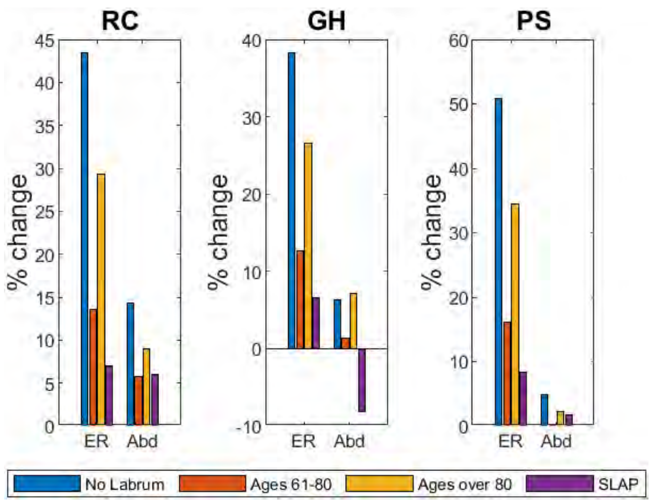

Figure 1: Means of percentage changes of muscle groups %MVC in isometric tasks.

Results: Rotator cuff muscles, glenohumeral articulating muscles, and periscapular muscles showed more than 10% increase in %MVC levels on conditions with no labrum, Ages between 61 to 80, ages over 80, and SLAP in external rotation (Figure 1) when compared to intact labrum condition. In abduction, rotator cuff muscles also showed increase in %MVC levels on same conditions and slightly increase in other two muscle groups (Figures 1).

Discussion and Conclusions: Rotator cuff glenohumeral stabilization behaviour coincided with previous work [3]. Simulated joint stability ratios reflective of labral damage increased muscle demands, suggesting fatigue development would occur more rapidly.

References:

[1] Lippitt & Matsen (1993). *Clin Orthop Relat Res (291)*
[2] Dickerson C. R. et al. (2007). *Comput Methods Biomech Biomed Engin* 10(6);
[3] Mulla, D. et al. (2020). *J Biomech* 100.

EFFECTS OF A SOFT HAND EXOSKELTON ON MUSCLE ACTIVIY DURING AN AUTOMOTIVE WELDING TASK

Daniel Cousins[1], Ryan Porto[2], Joel Cort[3,4], Michael Holmes[1]
[1]Faculty of Applied Health Sciences, Brock University, St.Catharines, ON
[2]General Motors, Warren, MI
[3]Faculty of Human Kinetics, University of Windsor, Windsor, ON
[4]Cort Research Innovation Inc, Tecumseh, ON

Introduction: Improving workplace ergonomics to reduce work-related musculoskeletal disorders involves constantly evaluating the benefits of new technologies. A soft-robotic glove (IronHand®, BioServo technologies, Kista, Sweden) is currently one of the only commercially available hand exoskeletons for occupational use. There has been one laboratory-based study examining the effects of IronHand® for occupational consideration [1]. Mayer et al. (2022) quantified forearm muscle activity across 3 conditions, including 2 pinch and 1 power grip while wearing IronHand®. The study revealed individual differences, which could attest to the difficulty of force augmentation at the hand. Therefore, the purpose of this study was to evaluate the use of IronHand® during a single automotive task, in the field. There were two hypotheses for this study, including: (1) there would be significant decreases in muscle activity over the full shift between wearing IronHand® and not wearing IronHand®; (2) there would be a significant interaction between hand placement on the tool and exoskeleton on muscle activity.

Methods: Four workers experienced in a two-handed suspended welder task for fenders and doors had muscle activity recorded during one shift with time split between wearing IronHand® (IH) and not (NH), and with hands driving the tool trigger and support. Muscle activity from 4 forearm (flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), extensor carpi radialis (ECR) and extensor carpi ulnaris (ECU)) and 2 shoulder muscles (anterior deltoid (DeltA) and medial deltoid (DeltM)) were recorded during the entire shift using a bipolar wireless surface electromyography system (Trigno™, Delsys, Natick, USA). The amplitude probability distribution function (APDF) was used to calculate 10th, 50th and 90th percentile muscle activity.

Results: For $APDF_{50}$ there was a significant increase in ECU from 6.3 ± 0.3% MVE to 7.5 ± 0.4% MVE (p =0.04) when wearing IH. ECR had a significant interaction demonstrating a decrease from 2.8 ± 0.2% MVE to 2.1 ± 0.2% MVE (p =0.012) when using IH for the trigger hand. The same was found in both DeltM from 3.9 ± 0.2 15% MVE to 3.3 ± 0.2% MVE (p =0.028) and DeltA from 1.1 ± 0.1% MVE to 0.9 ± 0.06% MVE (p =0.039). For peak activity ($APDF_{90}$) there was a significant interaction for ECU showing an increase from 36.1 ± 1.4% MVE to 42.1 ± 1.6 %MVE (p =0.006) when IH was worn on the support hand.

Discussion and Conclusions: When there were decreases in muscle activity with IH (as compared to NH), the documented changes in muscle activity were small. Not all muscles or participants responded the same way to the intervention. This is supported by a redundant forearm muscular system where different neuromuscular strategies could be used to accomplish the weld task [2]. This leads to the possibility of specific use cases, where the device would be beneficial.

References:

[1] Mayer TA et al. (2022). Effects of an active hand exoskeleton on forearm muscle activity in industrial assembly grips. Work 72 (4); p. 1577-1591.
[2] Forman DA et al. (2019). The influence of simultaneous handgrip force and wrist force on forearm muscle recruitment. J Electromyogr Kinesiol 45; p. 53-60.

INVESTIGATING THE RELIABILITY AND VALIDITY OF SUBACROMIAL SPACE MEASUREMENTS USING ULTRASOUND AND MRI

Stephen M. Boulanger[1], Alexandra Mahna[1], Anthony A. Gatti[2], Talia Alenabi[3], Oriana Culig[1], Jaclyn N. Chopp-Hurley[1]
[1] Kinesiology and Health Science, York University, Toronto, ON; [2]Radiology, Stanford University, Stanford, CA; [3] Kinesiology, University of Waterloo, Waterloo, ON

Introduction: The subacromial space (SAS) of the shoulder is an important measure for estimating the risk of subacromial impingement syndrome. While ultrasound (US) measures of the SAS have demonstrated excellent reliability [1], measurements are typically captured by experts with extensive clinical ultrasound experience [2-3]. Further, due to the imaging constraints of ultrasound, the absolute minimum SAS magnitude may be underestimated. As such, the purpose of this study was two-fold: (1) to evaluate the agreement in US SAS measures between a novice with introductory training and an expert, (2) to evaluate the SAS agreement between US and MRI.

Methods: 18 healthy young adults (9M/9W) participated. Two researchers (novice and expert raters) each captured three SAS measurements while the participant was in supine and seated positions using a GE Logiq ultrasound system [2] (Fig. 1). For each rater, and position, a mean SAS was calculated. Shoulder MRIs were also collected, and segmentations of the humerus and acromion were completed in open-source software (https://www.slicer.org/). An open-source algorithm (https://github.com/gattia/pymskt) was used to calculate the distance between the acromion and the humerus using normal projections from the bone surfaces (Fig 1).

Results: Intraclass correlation coefficients (ICCs) between novice and expert SAS measures were 0.74 and 0.63 for seated and supine positions, respectively. Intra-rater agreement was high for both novice (ICC=0.84) and expert (ICC≥0.94). Generally, the novice overestimated the SAS compared to the expert (1.3-1.4mm). ICCs between US and MRI ranged from 0.21-0.49 with the novice having lower agreement than expert, and supine having higher agreement than sitting.

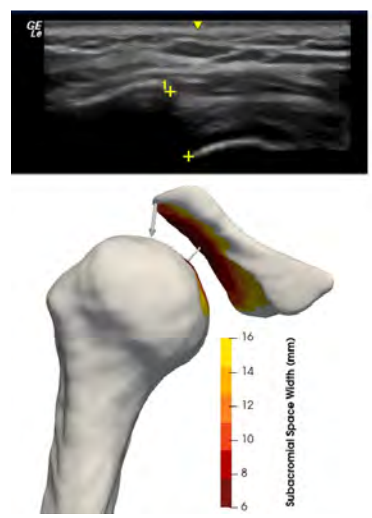

Fig 1. SAS measured from US (top) and MRI (bottom)

Discussion and Conclusions: Agreement between novice and expert SAS measures was moderate, while agreement with MRI was poor to fair. Mean differences in magnitude between imaging modalities for the expert rater was 1-2mm (novice ~3mm) however these differences were variable (~3-6mm). Thus, with high intra-rater agreement, this research suggests that a novice with introductory training may complete SAS measures, however, it may be more appropriate with a repeated measures design where within session changes are being compared rather than the true minimum SAS, which may be over- or under- estimated by US.

References:

[1] McCreesh et al. (2015). Br J Sports Med, 49(5); 298–305; [2] Desmeules et al. 2004. Clin J Sport Med. 14(4):197-205; [3] Hougs Kjær et al. 2017. Physiother Theory Pract. 33(5):398-409

QUANTIFYING THE EFFECTS OF FOOTBALL SHOULDER PADS ON REACH DISTANCE AND PLAYER PERCEPTION OF COMFORT AND FIT

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[2]Xenith, MI, USA

Introduction: The majority of sports equipment research to date has focused on their protective capabilities, and not on how they impact player performance and comfort while using them [1]. Evaluations of how sports protective equipment impact player performance and player perceptions of equipment comfort and fit, are relatively new and emerging concepts in the literature [2,3]. Therefore, the purpose of this study was to create a standardized methodology to quantify the effects of football shoulder pads on player reach distance and determine players' perceptions of comfort and fit for two models of shoulder pad (standard, prototype).

Methods: Ten current or former players participated in this study. Five GoPro Hero 9 cameras (GoPro inc., CA, USA) were used to record the movement sequences – three trials of flexion, extension, abduction, horizontal extension, and horizontal flexion, in each of three pad conditions (no shoulder pad, standard shoulder pad, prototype shoulder pad) while strapped to a stabilization device. The questionnaire included questions on pad breathability, weight, restriction, discomfort, and their likes and dislikes. Marker tracking was completed in ProAnalyst® (Xcitex, MA, USA), from which reach distances were calculated.

Results: Reach distances were significantly impacted during several movements, but especially for flexion and abduction: mean differences between the prototype pad and standard pad were 10.3cm and 23.1cm, respectively. Mean differences in reach distance were greater for the standard shoulder pad than the prototype shoulder pad, compared to when no shoulder pad was worn (Fig. 1). Participants found the prototype shoulder pad to be significantly lighter, and more breathable. Significantly more discomfort was reported in the neck collar and armpit regions for the standard pad compared to the prototype pad.

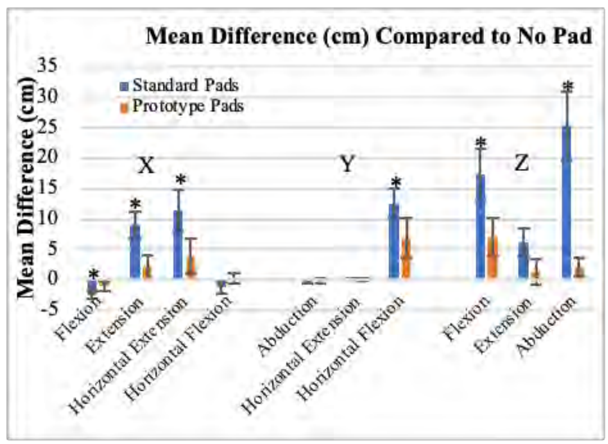

Figure 1: Mean (±SE) difference (cm) in reach distance between the no shoulder pad condition and the two pad conditions (standard, prototype). *p<0.05 compared to no shoulder pad condition.

Discussion and Conclusions: These findings have meaningful practical implications. The diameter of a standard size football is ~17cm, which is less than the mean difference in reach distance between the prototype and standard shoulder pads in abduction (Z). The differences found in reach distances, comfort and fit between the two shoulder pads studied herein provide manufacturers with valuable insights from a design standpoint, and can assist players when selecting equipment that may give them a performance advantage.

References:

[1] Barstch et al. (2012). Impact test comparisons of 20th and 21st century American football helmets. Journal of Neurosurgery 116; p. 222-33.
[2] Frayne et al. (2019). National hockey league equipment regulation effects on goaltender reach envelope. ISB Conference Abstract.
[3] Virani et al. (2017). The effect of shoulder pad design on head impact severity during checking. Medicine and Science in Sports and Exercise 49; p. 573-80.

FRONTAL PLANE KNEE LOADING DURING COMMON LIFTING TECHNIQUES

Kimberly H. Peckett[1], Terri E. Weeks[1], David J. Varandas[1], Stacey M. Acker[1]
[1]Kinesiology and Health Sciences, University of Waterloo, Waterloo, ON

Introduction: Past literature on lifting techniques has mainly focused on the back, recommending deep knee flexion to maintain an upright back posture [1,2]. However, frequent deep knee bending has been associated with knee osteoarthritis development [3]. Although the back is the most reported injury site in childcare and home support workers, injuries to the lower extremities, including the knee, are the second most reported [4]. This study aims to compare knee adduction moment (KAM) and KAM impulse of both knees during three techniques used to lift children off the floor (stoop, squat, and straddle).

Methods: Thirteen healthy participants were recruited for this study. Each participant completed three randomized trials of each lift, lifting an 11kg sandbag intended to simulate a 90^{th} percentile infant [5]. Between lifts, participants performed a non-strenuous task for 4 minutes to ensure a lifting frequency of 0.25 lifts/min [6]. Motion data of the pelvis, thighs, shanks, and feet, and ground reaction force data were recorded. KAM and KAM impulse was calculated in Visual 3D. A two-way (lift type x leg) ANOVA for KAM and KAM impulse was performed ($\alpha=0.05$).

Results: For all outcome variables, there were significant leg x lift type interactions. For both the pickup and put down stages of the lift, the left leg demonstrated significantly higher KAM and impulse during the straddle lift compared to the squat lift ($p<0.01$). There was no significant difference in the left leg between any of the other lifts. The KAM of the right leg during all three lifts were significantly different from each other, with the squat having the lowest KAM, and stoop having the highest KAM. Impulse during both stages of the lift showed no significant difference in the right leg between the squat and the straddle, but there was a significant increase in impulse during the stoop lift compared to the squat ($p<0.02$), and a significant increase during the stoop lift compared to the straddle ($p<0.03$). For both squat and straddle, KAM and KAM impulse of the left and right leg were significantly different ($p<0.01$), while for stoop, there was no significant difference between legs.

Discussion and Conclusions: When lifting a flexible sandbag, mimicking how the participant would lift a child, we observed that hand placement may be affecting the knee joint load, which was not seen previously in studies lifting rigid crates [7]. For example, the squat is described as a symmetrical lift, however KAM and KAM impulse are significantly different between the left and right leg when lifting the sandbag, with large variability across participants, possibly due to their preference in hand placement. The straddle lift also had significantly different KAM and KAM impulse between the right and left leg, though the pattern of difference is more consistent across participants compared to squat. For the straddle lift, the back leg always experienced less KAM and impulse than the front leg. From this finding, we recommend alternating legs when using the straddle lift to ensure less cumulative load focused on one leg. We also recommend, if you have an injured leg, to put your injured leg as your back leg during the straddle lift to reduce frontal plane loading of the injured leg.

References:

[1] Bejjani FJ et al. (1984). *J. Biomech*, *17*(4), 281–286 **[2]** Schipplein OD et al. (1990). *J. Biomech*, *23*(9), 907–912. **[3]** Coggon D et al. (2000). *Arthritis and Rheumatol*, *43*(7), 1443–1449. **[4]** WSIB Ontario. (2020) By the numbers: 2020 Statistical Report. **[5]** WHO. (2006) WHO *Acta paediatrica*, *450*, 76–85 **[6]** Labaj A et al. (2019). *Int. J. Ind. Ergon*, *69*, 96–103. **[7]** Kingma I et al. (2006). *Physical Therapy*, *86*(8), 1091–1105.

QUANTIFYING KNEE BRACE PERTURBATION RESPONSES DURING GAIT

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[2,3] Schools of Physiotherapy and Biomedical Engineering, Dalhousie University, Halifax, NS

Introduction: Knee instability is associated with impaired joint function that has implications for continued mobility when knee injury is present [1]. To better understand how instability impacts knee function, research that challenges knee stability is needed. Gait perturbation research is novel but limited to unexpected walking surface translations [2], [3]. The purpose of this study was to validate a custom knee brace perturbation device that *directly* challenges the knee joint during gait in healthy young adults. It was hypothesized that step length and width (SL, SW) would decrease, and muscle co-contraction would increase following direct knee perturbations.

Brace.

Methods: Eighteen healthy participants (10 female) completed this REB approved study. Individuals were instrumented with surface **electromyography** (EMG) (Bortec Inc., Canada) on the right medial and lateral vasti (MQ, LQ), hamstrings (MH, LH), and gastrocnemii (MG, LG), full-body **reflective markers** for kinematic tracking (Qualisys®, Sweden) [3], and a **custom brace** (Figure 1). A pneumatic actuator delivered unexpected perturbations to the lateral knee (duration = 0.2s, max 150N) while subjects walked barefoot on a treadmill (Motekforce Link, Netherlands) for 15-minutes. Trials included baseline, and six single-perturbations in random order: 3 during double support (DS), and 3 during single support (SS). Data were processed in MatLab™ 2021b (MathWorks Inc., USA). *SL* and *SW* were computed using anterior and lateral distances between heel markers at heel strike. EMG were normalized to dynamometer (Computer Sports Medicine Inc., USA) maximum voluntary isometric contraction, and *co-contraction* indices were averaged for LQ-LH, LQ-LG, MQ-MH and MQ-MG over weight acceptance (WA) and midstance [2]. *SL*, *SW,* and *co-contraction* were compared between baseline and the first post-perturbation strides using one-factor repeated measures ANOVAs and Bonferroni *post hoc* tests.

Results: Post-perturbation, there was no change in SL or SW ($p > 0.05$), but some muscle co-contractions during WA increased after both the DS and SS timed perturbations (Table 1).

Table 1: Mean (SE) increase in muscle co-contraction during WA (* indicates $p < 0.05$).

Timing	**LQ-LH**	**LQ-LG**	**MQ-MG**
DS	0.09 (0.04)	0.14 (0.05) *****	0.25 (0.09) *****
SS	0.13 (0.04) *****	0.12 (0.06)	0.26 (0.09) *****

Discussion and Conclusions: Brace-applied knee joint perturbations during the weight bearing period of gait elicited neuromuscular responses, thought to preserve joint function for continued mobility. While results are consistent with previous gait perturbation literature [2], [3], this device provides opportunities to test responses during other functional tasks where stability is challenged.

References:

[1] Fitzgerald K. et al. (2004). Reports of joint instability in knee osteoarthritis: Its prevalence and relationship to physical function. Arthritis Care & Research (51); p.941-946.

THE EFFECT OF ADJUSTING FRONTAL PLANE KNEE ALIGNMENT WHEN SCALING PATIENT-SPECIFIC NEUROMUSCULOSKELETAL MODELS IN PATIENTS WITH KNEE OSTEOARTHRITIS

Dominique Cava[1], Trevor Birmingham[2], Kristyn Leitch[1], Ryan Willing[3]
[1]Health and Rehabilitation Sciences, Western University, London, ON
[2]School of Physical Therapy, Western University, London, ON
[3]Mechanical and Materials Engineering, Western University, London, ON

Introduction: Knee osteoarthritis (OA) is complex and includes aberrant mechanical loads across the tibiofemoral joint during ambulation that cannot be directly measured in the intact knee [1]. Patient-specific EMG-assisted computational neuromusculoskeletal (NMS) models offer a means to estimate these loads. The distribution of loads on the knee is affected by lower limb frontal plane alignment (a known risk factor for OA progression), yet standard musculoskeletal models often do not account for alignment [2]. The purpose of this study was to compare preliminary results from standard and alignment-predicted patient-specific EMG-assisted computational NMS models in patients with varus alignment and medial compartment knee OA.

Methods: Gait data were collected from 23 (age=52 ±5 years; 16 males and 6 female) varus aligned patients with symptomatic and radiographic (KL grade 2 or 3) knee OA primarily affecting the medial compartment of the tibiofemoral joint (mechanical axis angle [MAA]=6.4^{o} ±1.8^{o} varus). With these data, two generic models were scaled in OpenSim v4.1 for each participant. The "standard model" underwent a standard method of scaling using the patients' anthropometric data from a static trial, which does not adjust knee frontal plane alignment (i.e., MAA fixed at 0^{o}). The second "alignment-predicted" model was enabled to predict the patient-specific frontal plane alignment based on the anthropometric data during scaling. The predicted value was then fixed after scaling for the remainder of the analyses (model predicted MAA=7.6^{o} ±2.5^{o} varus). Kinematic and kinetic data from both models were provided as inputs to an inverse dynamics analysis. Computational EMG-assisted NMS models were then executed in CEINMS for both models with experimental activations and OpenSim computed knee flexion external torques and kinematics as inputs. Computed knee flexion internal (muscle-based) torques were compared to corresponding OpenSim computed external torques to provide a measure of the model's prediction accuracy.

Results: The root mean square error (RMSE) between internal and OpenSim computed external knee flexion torques using the standard model was 7.3 Nm (±1.7) and decreased to 4.4 Nm (±0.95; 40% smaller) for the alignment-predicted model.

Discussion and Conclusions: Frontal plane knee alignment is an important yet often neglected parameter in NMS model predictions. Preliminary results suggested that adjusting knee alignment improved model prediction accuracy for patients with knee OA.

References:

[1] Andriacchi and Mündermann (2006). The role of ambulatory mechanics in the initiation and progression of knee osteoarthritis. Current Opinion in Rheumatology 18 (5); p. 514-518.
[2] Bowd et al. (2023). Using musculoskeletal modelling to estimate knee joint loading pre and

Podium Session 6

Thurs May 11

9:00A-10:10A

CHAIRS & AFFILIATIONS

Prasannaah Hadagali - University of Waterloo & Daniel Armstrong - University of Waterloo

9:00-9:10	Mohammad Mohammad Queen's University	Estimating Energy Expenditure Using Wearable Sensors During Indoor And Outdoor Locomotion
9:10-9:20	Kevin Kos via Dan Mulla McMaster University	Upper Body Joint Moment Trade-Offs
9:20-9:30	Daniel Genaro University of Guelph	Optimizing Lower-Limb Sensory Substitution
9:30-9:40	Aurora Battis Brock University	Assessing The Acute Effects Of Wearable Sensor Derived Auditory Biofeedback On Gross Lumbar Proprioception
9:40-9:50	Steven Pretty University of Waterloo	Force Transmission During Lateral Falls Is Dependent On Hip Protectors And Soft Tissue Thickness
9:50-10:00	Jakub Targosinski Western University	An In Vitro Study Of Glenoid Implant Peripheral Peg Interface Mechanics Under Simulated Glenoid Lift-Off Loading
10:00-10:10	Ryan Foley Ontario Tech University	Modeling The Effect Of Unique Force-Time Histories On Predicted Muscle Fatigue

ESTIMATING ENERGY EXPENDITURE USING WEARABLE SENSORS DURING INDOOR AND OUTDOOR LOCOMOTION

Mohammad Mohammad[1], Abed Abu Hijleh[1], Jessica Selinger[1]
[1]School of Kinesiology and Health Studies, Queen's University, Kingston, ON

Introduction: Measures of metabolic energy expenditure can provide valuable insight into healthy and impaired gait, the design and control of assistive devices, and rehabilitation progress [1,2]. Currently, the gold standard for estimating expenditure is indirect calorimetry, where gas exchange is captured at the mouth [3]. Although accurate, indirect calorimetry systems are expensive, cumbersome, and often limited to lab settings. Therefore, our aim is to develop a cheap, lightweight method for estimating energy expenditure using wearable sensors.

Methods: *Participants.* We recruited healthy adults who are recreational runners (n=22, 11F). *Equipment.* Each participant was instrumented with a Cosmed® K5 portable indirect calorimetry system (Cosmed®, IL, USA) to measure energy expenditure, as well as the following wearable sensors to estimate energy expenditure: a CXL10LP3 3-axis accelerometer at the pelvis and foot (Crossbow®, MA, USA) and a T34 heart rate (HR) monitor (Polar®, ON, Canada). *Protocol.* Participants walked and ran on either a treadmill or a predefined outdoor route at varying speeds, inclines and added weight conditions. *Analysis.* We used multiple regression (MLR) analysis, as well as long short-term memory recursive neural network (NN), with a leave-one-out cross-validation design to predict energy expenditure using custom metrics derived from wearable sensors and anthropometric data.

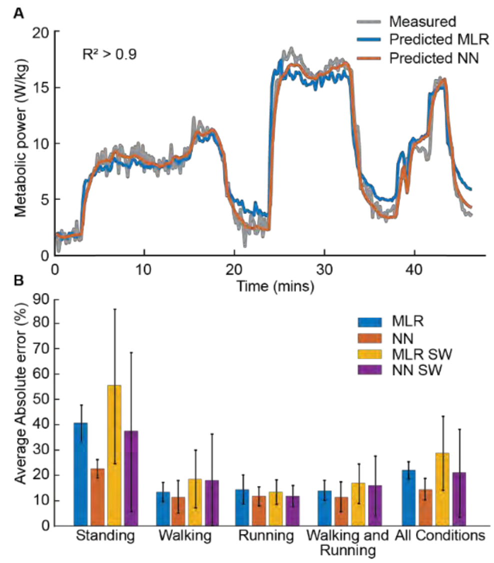

Figure 1: ***A)* Measured and predicted metabolic power timeseries for a representative participant. *B)* Average absolute percent error between measured and predicted metabolic power using full MLR and NN models, as well as smartwatch (SW) models.**

Results: We found that our NN method has an average absolute error of 14%, which is among the most accurate wearable sensor methods [2,3]. We also found low error rates using only data available from a typical smartwatch (SW model). The correlation (R^2) between measured and predicted energy expenditure was above 0.9 in all models (Figure 1a). Average absolute errors in estimated energy expenditure were typically ~0.9 W/kg. This resulted in lower percent errors for higher work rate tasks (e.g., running), and higher percent errors at lower work rates (Figure 1b).

Discussion and Conclusions: Development of a cheap, lightweight method for accurately estimating energy expenditure could allow researchers and clinicians to predict energy expenditure outside lab settings, for extended periods, and in diverse populations [3].

References:
[1] Benson L et al. (2018). Gait Postur 63: p. 124-38.
[2] Ingraham K et al. (2019). J Appl Physiol 126 (3): p. 717-29.
[3] Slade P et al. (2021). Nat Commu 12: p. 4312.

“SUBTLE” KINEMATIC CHANGES DURING ONE-ARM PULLING AND THEIR IMPLICATIONS ON UPPER EXTREMITY AND TRUNK MOMENTS

Kevin Kos†, Daanish M. Mulla, Peter J. Keir
Department of Kinesiology, McMaster University, Hamilton, ON

Introduction: Repetitive tasks can induce “subtle” joint kinematic changes (defined here as < 5°) that are task- and individual-dependent [1, 2]. However, the question remains, do slight kinematic variations have meaningful implications on tissue demands? We implemented a sagittal-plane biomechanical model to explore the effects of task- and individual-variability on upper body joint moments and examine load re-distributions with “subtle” kinematic changes.
Methods: Probabilistic modelling was used to determine the effects of anthropometric variability and kinematic changes on joint demands during a 50 N static pull task at four reach heights. Virtual individuals were generated by sampling from adult population anthropometrics. We developed an anthropometrically scaled biomechanical model to solve for optimal individual-specific kinematics across reach heights. Optimized kinematics were altered at each upper extremity joint by ± 5° to simulate “subtle” kinematic changes and their impact on joint moments.
Results: We observed statistically significant difference in the variability of joint demands across reach heights ($p<0.001$). When predicting optimal postures, greater population variability in back moments is observed at low reach heights, while elbow and shoulder moments variability increased at higher reach heights (Figure 1). Perturbing joint angles from the optimal posture resulted in joint moment changes of 0.0-1.2 Nm (elbow), 0.0-1.7 Nm (shoulder), and 0.0-15.3 Nm (trunk), varying depending on sex, reach height, and perturbation direction.
Discussion/Conclusion: Variation in joint moments differ across tasks, indicating task conditions that may be onerous on specific joints for select population of workers depending upon their anthropometrics. Perturbing joint kinematics within ± 5° altered joint moments up to 10% of average population strength, reflecting possible meaningful changes in joint demands, but differing greatly across individuals. This finding suggests that anthropometric differences alone can cause substantial inter-individual variability in joint demands when compensating for fatigue.
References: 1. McDonald (2019) Appl Ergon 75:250-256; 2. Mulla (2020) Appl Ergon. 88:103142.
Acknowledgement: †In memory of Kevin Kos, who sadly passed away on April 18, 2022.

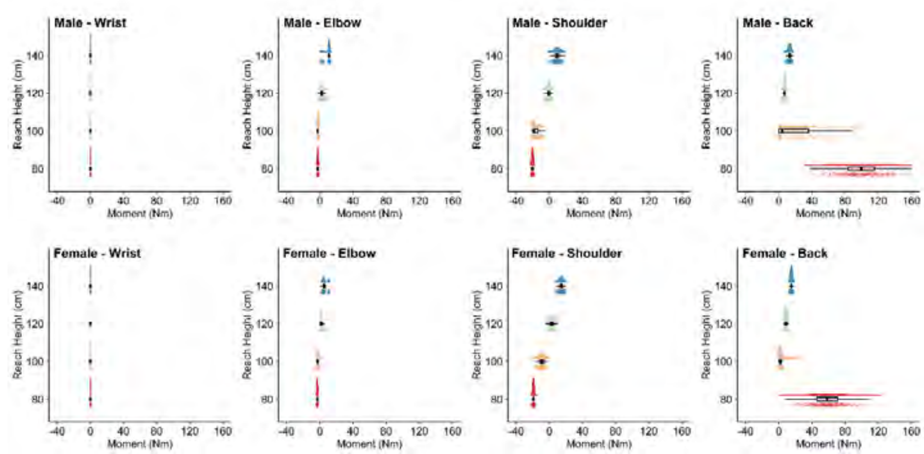

Figure 1: Optimized external joint moments plotted against reach height. Positive moments represent wrist ulnar deviation, elbow extension, shoulder extension, and trunk flexion, respectively.

FEELING THE VIBES: OPTIMIZING VIBRATORY ACTUATOR SPACING FOR SENSORY SUBSTITUTION IN LOWER-LIMB PROSTHESIS

Daniel Genaro[1], Laura Marrelli[1], Erika Howe[1], Michael Apollinaro[1], Leah Bent[1]
[1]Human Health and Nutritional Sciences, University of Guelph, Guelph, ON

Introduction: Lower-limb prostheses can restore mobility, however, individuals with amputations face challenges in postural control due to the lack of somatosensory feedback. Sensory substitution is a non-invasive approach that provides artificial sensory feedback by using patterns of vibration on a grid located at the thigh to represent relevant cues such as limb flexion. For this technique to be effective, careful consideration must be given to the spacing between vibratory actuators and vibration frequency to ensure that the cues are correctly interpreted.

Methods: The study recruited fifteen female students from the University of Guelph. A mini shaker (Brüel & Kjær Type 4810, Nærum, Denmark) with probes spaced at 20, 25, and 30 mm, and vibrating at either 30 or 150 Hz was used to deliver a 1s vibration on the middle of the participants' thigh. The probes were positioned either vertically or horizontally and the participants were asked to report the orientation of the probes, and the % of correct response was used as an outcome measure. The effects of distance and frequency were tested using a 2x3 repeated-measures ANOVA, and a simple linear regression of distance/thigh length and accuracy was also conducted. Significance was set to $p<0.05$.

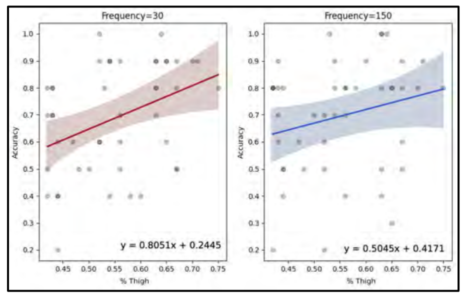

Figure 1: Relationship between the normalized distance (% Thigh) and accuracy. Bands represent the standard error.

Results: Significant main effects were found for frequency ($p <.05$, $\eta^2p= 0.386$) but not for distance ($p = .132$, $\eta^2p= 0.144$) when using thigh length as a covariate. The regression analysis using the normalized distance as a predictor showed that it significantly predicted variation in accuracy, with a larger effect for the 30 Hz conditions ($R^2= .146$; $p = .01$) than the 150 Hz conditions ($R^2=.054$;$p = .123$). This suggests that the relationship between normalized distance and skin's spatial acuity is stronger at lower frequencies.

Discussion and Conclusions: We found that normalized distance resulted in higher accuracy and had a greater effect on accuracy at 30Hz compared to 150Hz, suggesting that greater spacing may be needed for 30Hz vibrations. This contradicts assumptions about the receptors traditionally targeted by 30Hz in glabrous skin, which can distinguish cues at closer distances. In hairy skin, 30Hz is thought to target hair receptors, which may have wider receptive fields, that can benefit from larger distances between actuators These findings underscore the importance of considering both frequency and thigh length when selecting the spacing of vibrating actuators.

References:

[1] Wong C, et al. (2016). Risk of fall-related injury in people with lower-limb amputation. J Rehabil Med 48 (1); p. 80-85.

ASSESSING THE ACUTE EFFECTS OF WEARABLE SENSOR DERIVED AUDITORY BIOFEEDBACK ON GROSS LUMBAR PROPRIOCEPTION

Aurora Battis, Shawn M. Beaudette
Department of Kinesiology, Brock University, St. Catharines ON

Introduction: Patients experiencing low back pain (LBP) exhibit impaired motor control patterns and proprioceptive deficits and may benefit from proprioceptive retraining [1]. Proprioception is typically quantified by assessing conscious control (e.g., active or passing re-matching tasks) or subconscious control (e.g., vibration evoked reflexes) [2]. The neuromuscular control of the spine operates in a feedback loop by incorporating afferent feedback to inform on a motor response [3]. The use of supplemental sensory inputs has become an area of importance for sensorimotor (re)training, with potential utility to optimize movement patterns, reverse central maladaptation(s), and aid with rehabilitation. Augmented biofeedback can be used as a training method that provides additional information to enhance performance through changed behaviours [4]. The **purpose** of this study is to explore the potential utility of wearable sensor derived auditory biofeedback on the proprioception of the lumbar spine in a sample of young, healthy participants. It is **hypothesized** that auditory biofeedback training will be effective at acutely improving accuracy (CE, AE) and precision (VE) of lumbar spine sagittal plane repositioning.

Methods: 28 healthy young adults (14 females) participated (age= 22.9 ± 3.4 yrs; height=172.8 ± 9.5 cm; weight=73.4 ± 13.9 kg). Participants were instrumented with a wireless electrogoniometer (T12-S1) and remained in an ergonomic kneeling chair for all interventions and assessments. Three maximum flexion ROM trials were completed to derive four targets: 20%, 40%, 60%, and 80% of their ROM. Participants were familiarized with each target prior to the pre-training test. The pre-training test consisted of an active flexion repositioning task five times/target in a random order. Two of the four targets were randomly selected (one each ± 50% ROM) and trained for five minutes each with augmented auditory feedback, derived from the electrogoniometer. Participants completed a post-training test which mirrored the pre-training test to evaluate acute effects of auditory training.

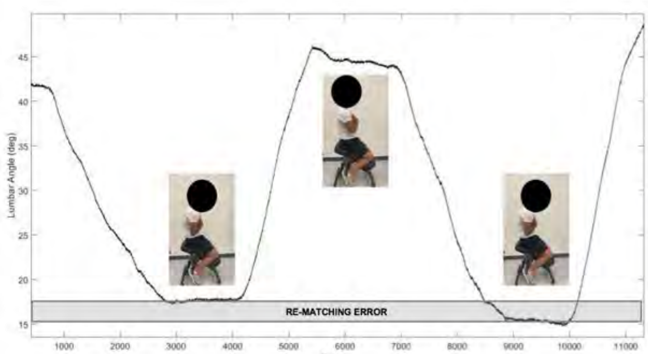

Figure 1: Representative data depicting repositioning task and error for a single participant.

Results: Although statistically insignificant ($p > 0.05$), positive effects were observed across all targets. The targets with the strongest effects were the mid-range targets (i.e., 40% and 60% max ROM). Moderate-to-strong linear regressions indicate that those with the poorest re-matching abilities at baseline demonstrated the strongest benefits of the acute auditory biofeedback.

Discussion and Conclusions: The findings reported here represent a proof of principle that acute auditory biofeedback training has the capacity to improve lumbar proprioception in a population of healthy young participants. Although baseline proprioception varied, significant effects may be masked by the elevated abilities in this sample of young, healthy participants. These findings suggest that this type of proprioceptive re-training technique may be of use in a clinical population where proprioceptive deficits are present.

References:

[1] van Dieën et al., 2019. J Orthop Sports Phys Ther. 49(6): 380–88; [2] Brumagne et al., 2000. Spine. 25(8): 989-94; [3] Reeves et al., 2007. Clin Biomech. 22(3): 266-274; [4] Alhasan et al., 2017. Clin Interv Aging. 12: 487-497.

The Influence of Trochanteric Soft Tissue Thickness and Hip Protector Use on Force Transmission During Lateral Falls

Steven P. Pretty, Alyssa Tondat, Taylor Winberg, & Andrew C. Laing
Department of Kinesiology and Health Sciences, University of Waterloo, Waterloo, ON

Introduction: Increased trochanteric soft tissue thickness (TSTT) over the hip is associated with reduced risk of hip fracture. The protective effect of these tissues is largely attributed to increased impact force attenuation and redistribution during falls [1]. External protective garments worn over the proximal femur (hip protectors) are recommended to provide additional impact attenuation, particularly among individuals with low TSTT [2]. The objective of this study was to evaluate the relationships between TSTT and impact forces at the skin surface and femoral neck during lateral impacts with and without a commercial hip protector (HipSaver).

Methods: The soft tissues overlying the proximal femur were isolated from nine fresh cadaveric femora. Prior to dissection from the femur, TSTT was measured via ultrasound with the greater trochanter directed upwards. Soft tissue pads (10 x 10 cm) centered about the greater trochanter were affixed to a surrogate pelvis and placed in a drop tower system. Femoral geometry, pelvic stiffness, effective mass, and drop height were selected to simulate a fall from standing height in an older adult female [2]. Each soft tissue sample underwent both unpadded and protected 2 m/s impacts. For each impact, peak skin surface and femoral neck forces were extracted from a force platform and saw-bone mounted loadcell, respectively. Force attenuation from the skin surface to the femoral neck ($ATTEN_{TST}$) was expressed as a percentage of peak skin surface force. Hip protector efficacy was expressed as the percentage reduction in peak skin surface ($HP\text{-}EF_{SS}$) and femoral neck ($HP\text{-}EF_{FN}$) forces during protected compared to unpadded trials. Bi-variate Pearson correlations (two-tail) were performed to assess the relationships between TSTT and impact forces (skin surface and femoral neck), as well as $ATTEN_{TST}$, $HP\text{-}EF_{SS}$, and $HP\text{-}EF_{FN}$.

Results: During unprotected trials, each 1 mm increase in TSTT was associated with 41.6 and 46.3 N decreases in peak skin surface ($r^2 = 0.86$) and femoral neck forces ($r^2 = 0.84$), respectively ($p < 0.001$). TSTT was positively correlated with $ATTEN_{TST}$, indicative of force redistribution away from the proximal femur (7.3% per mm; $r^2 = 0.50$; $p = 0.034$). During protected trials the effect of TSTT was less pronounced. Each 1 mm increase in TSTT was associated with 11.5 and 18.5 N decreases in peak skin surface ($r^2 = 0.53$; $p = 0.027$) and femoral neck forces ($r^2 = 0.46$; $p = 0.043$), respectively. $HP\text{-}EF_{SS}$ and $HP\text{-}EF_{FN}$ decreased 8.6 and 10.6% per mm TSTT (both $r^2 = 0.82$; $p = 0.001$). $HP\text{-}EF_{FN}$ was 40.6% for the lowest TSTT specimen (10.4 mm) but decreased to 0.0% (i.e. no benefit) for the highest TSTT specimen (40.2 mm). During protected trials, TSTT was not correlated with $ATTEN_{TST}$ ($p = 0.171$), suggesting hip protector use normalized force transmission between the skin surface and femoral neck across low and high TSTT specimens.

Discussion and Conclusions: These results support previous reports of a linear decrease in femoral neck force with increasing TSTT [2]. Interestingly, the current data suggest that for high-TSTT individuals (>40 mm) hip protector use may increase femoral neck force due to load concentration over the proximal femur. Pressure analyses will further explore these relationships.

References:

[1] Robinovitch et al. (1995). *J Ortho Res* (13):956-62. [2] CSA Group (2020). CSAZ325:20.

AN IN VITRO STUDY OF GLENOID IMPLANT PERIPHERAL PEG INTERFACE MECHANICS UNDER SIMULATED GLENOID LIFT-OFF LOADING

Jakub R. Targosinski[1], Jonathan Kusins[1], Louis Ferreira[1] George Athwal[2] Andrew Nelson[3]
[1]Department of Mechanical and Materials Engineering, Western University, London, ON
[2]Schulich School of Medicine and Dentistry, Western University, London, ON
[3]Department of Anthropology, Western University, London, ON

Introduction: Aseptic loosening of the glenoid implant over time remains one of the most common modes of failure in anatomic total shoulder arthroplasty [1,2]. Glenoid implant loosening is caused by the rocking horse mechanism, whereby cyclic loading of the implant causes progressive damage to the implant-bone interface. Glenoid implants typically incorporate a central peg flanked by peripheral pegs designed to accommodate the large superior-inferior loads generated through the rocking-horse mechanism. Digital volume correlation and micro-computed tomography can provide mechanical information about the interface between glenoid peripheral pegs, the cement mantle, and the underlying trabecular bone.

Methods: 10 (n=5, tensile/compressive loading) bone cores were implanted with a glenoid peripheral peg and the specimens were mechanically loaded inside of a cone beam micro-CT scanner. Stepwise compressive and tensile displacements were applied to these constructs (Figure 1). DVC-derived maximum and minimum principal strains were calculated at locations of interest inside the peg-cement-bone interface.

Results: For the tensile loading mode, there was a significant main effect of axial and lateral distance from the peg ((F(3)=97.41, p<.001), (F(1)=90.57 , p<.001)) on the magnitude of the maximum and minimum principal strains measured. Highest strains were found near the root of the peg, and decreased with lateral and axial distance away from the peg. The results were similar for the compressive loading mode, with the same trend as the tensile loading mode for axial and lateral distance. (F(3)=290.13, p<.001, (F(1)=7654.69, p<.001),

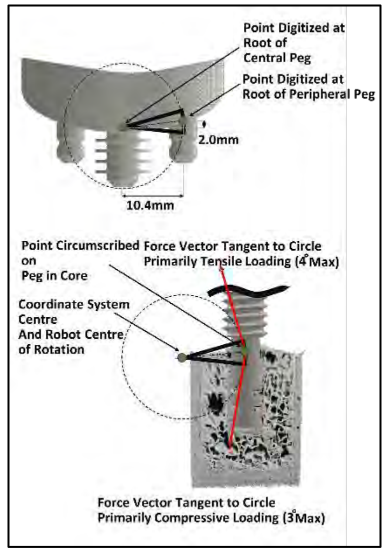

Figure 1: Coordinate system and loading of cores relative to glenoid implant

Discussion and Conclusions: Locations near the root of the peg experience the highest principal strains, of which the mean magnitude was higher than reported yield failure strains for trabecular bone tissue in both tension and compression. This location is a likely candidate for the initiation of failure of the glenoid implant-cement-bone interface.

References:
[1] Dines JS et al. (2006). Outcomes analysis of revision total shoulder replacement. Journal of Bone and Joint Surgery 88(7), p.1494-1500
[2] Bonnevialle N et al. (2013). Aseptic glenoid loosening or failure in total shoulder arthroplasty: revision with glenoid reimplantation. Journal of Shoulder and Elbow Surgery

MODELING THE EFFECT OF UNIQUE FORCE-TIME HISTORIES ON PREDICTED MUSCLE FATIGUE

Ryan C. A. Foley[1], Nicholas J. La Delfa[1]
[1]Faculty of Health Sciences (Kinesiology), Ontario Tech University, Oshawa, ON

Introduction: Several ergonomics methods exist to mitigate excessive muscle fatigue in the workplace for intermittent and isotonic force exertions. Recent advances allow for the estimation of workload thresholds for more ‘complex’ work, of varied intensities and durations, by breaking a cycle into sub-tasks and determining acceptable rest allowances [1]. However, these approaches do not consider the *order* or *pace* in which the efforts and rests occur, which may affect how fatigue develops over time. The purpose of this research was to investigate how different patterns of exertion and rest, of otherwise equivalent workloads, can affect predicted fatigue outcomes.

Methods: A computational motor unit fatigue model [2] was used to evaluate muscle fatigue across several representative simulations. Within each study, all intermittent force profiles had equivalent average force and duty cycle (% of task time producing effort). Cycles were repeated for 8 hours to represent a full day occupational task. The remaining strength capacity of all motor units served as the dependent variable. Study A - Order Effects: Profiles were divided into five 12-second segments to represent a 1-minute cycle. Each cycle consisted of three different exertion intensities (low:4.5%MVC, med:15%MVC, high:27.5%MVC) and 2 rests (0% MVC). The force profiles were differentiated according to two variables: 6 ‘patterns’ (the order of exertion level e.g. ‘high-low-medium’) x 10 ‘sequences’ (the distribution of exertions and rests e.g. ‘effort-rest-effort-rest-effort’) for a total of 60 profiles. Study B - Pacing Effects: Twelve different exertion frequencies (60 [i.e. 0.5s exertion, 0.5s rest], 30, 20, 15, 12, 10, 6, 5, 4, 3, 2, and 1 [i.e. 30s exertion, 30s rest]) with equivalent duty cycle of 0.5 were tested over a 1-min cycle while maintaining one of three exertion intensities (25%, 50%, 75% MVC).

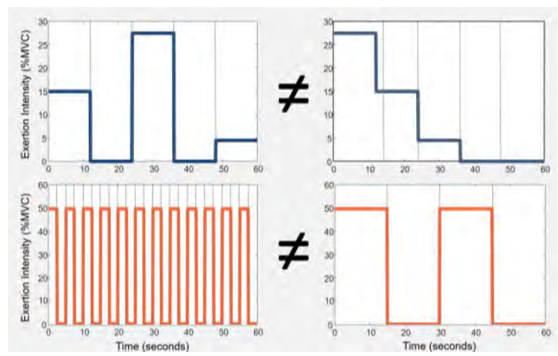

Figure 1: Despite the same overall workload per cycle, these studies showed different fatigue accumulation based on order (top) and pacing (bottom) of contractions.

Results: Order Effects: Fatigue varied up to 9.3%MVC between orders. Profiles that induced the most and least fatigue were the ‘high-med-low-rest-rest’ sequence (-46.31 %MVC) and the ‘med-rest-high-rest-low’ sequence (-37.05 %MVC), respectively. ‘High-med-low’ was the most fatiguing pattern (-42.97 ± 0.13 %MVC), likely due to a high force followed by no immediate rest. Pacing Effects: Lower frequencies demonstrated more fatigue, with 30s exertions showing 0.7%, 2.86% and 2.67% more fatigue than 0.5s exertions at 25%, 50%, 75% intensities, respectively.

Discussion and Conclusions: Despite equivalent average intensity and exertion time, the pattern of exertion had a noticeable effect on fatigue accumulation. In both studies, interspersing rest proved to be an effective strategy to mitigate fatigue accumulation. This modeling approach can inform work task resequencing to minimize muscle fatigue development in the workplace.

References:

[1] Gibson, M., & Potvin, J.R. (2016). An equation to calculate the recommended cumulative rest allowance across multiple subtasks. ACE Conference, Niagara Falls, ON.
[2] Potvin, J.R., & Fuglevand, A.J. (2017). A motor unit-based model of muscle fatigue. PLoS

Podium Session 7

Wed May 10

10:30A-11:40A

CHAIRS & AFFILIATIONS

Brendan Pinto - University of Waterloo & Jenna Pitman – University of Guelph

10:30-10:40	Cathrine Feier University of Guelph	Visual Cues During Sit-To-Stand
10:40-10:50	Jessica Wenghofer University of Ottawa	Markerless Spine Movement Assessment
10:50-11:00	Margaret Harington University of Toronto	Hip Musculoskeletal Model Validation
11:00-11:10	Garrick Forman Brock University	Forearm Muscle Fatigue And Computer Mouse Performance
11:10-11:20	Monica Malek McMaster University	Optoelectronic Motion Capture Protocol For In-Clinic Orthopaedic Gait Analysis
11:20-11:30	Emily Lefebvre York University	Subcutaneous Tissue, Muscle Quality, And EMG
11:30-11:40	Jackie Zehr University of Waterloo	Compression Induced Microinjury Patterns In The Spinal Endplate

THE EFFECT OF VISUAL CUES AT DIFFERENT HEIGHTS ON SIT-TO-STAND MOVEMENTS IN PEOPLE WITH AND WITHOUT LOW BACK PAIN

Cathrine H. Feier, Stephen H. M. Brown
Department of Human Health and Nutritional Sciences, University of Guelph, Guelph, ON

Introduction: Moving from a seated position to a standing position is a functional movement that demands a combination of strength, balance, and mobility. People with low back pain often report that getting up from a chair is both painful and difficult [1]. They may also display altered movement patterns when compared to asymptomatic individuals [2]. Using external cues to change people's movement strategies might be helpful in clinical settings. The aim of this research was to assess the effect of visual cues at different heights on the kinematics of sit-to-stand movements, as well as perceived difficulty and pain levels in people with and without low back pain.

Methods: We have thus far collected 14 participants (age: 22.2 ± 3.8 years, mass: 62 ± 8 kg, height: 1.68 ± 0.08 m, 12 females and 2 males, 13 without and 1 with low back pain). Participants had 96 retroreflective markers taped to key anatomical landmarks. Three-dimensional kinematic data were collected with 11 OptiTrack motion capture cameras at 120 Hz using Motive software (NaturalPoint Inc., Corvallis, OR, USA). All participants performed 5 x 5 sit-to-stand movements with three-minute breaks between sets (Figure 1). The stool used during trials was armless and backless, adjusted to the individual participant's fibular head height, and placed approximately 2 m from the wall they were facing. During sets 2, 3, and 4, participants were asked to keep their arms by their sides and fix their gaze on a colorful visual cue on the wall throughout the movement. The cue was placed at eye level in the seated position (MIDDLE), close to the ceiling (HIGH), or close to the floor (LOW) in a randomized order. Movements were performed at a normal, comfortable speed with a short break between each repetition. Perceived difficulty and pain levels were assessed after each set of 5 repetitions.

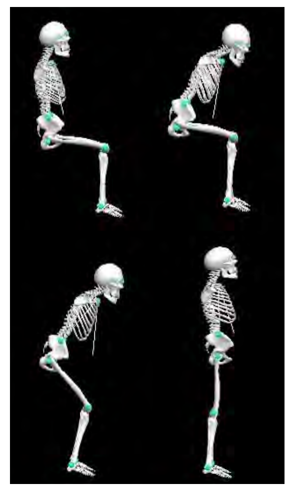

Figure 1: Example of a sit-to-stand trial.

Results: When comparing values within each participant, we found that 86% of the participants displayed the highest peak trunk flexion angle (averaged across trials) during the LOW trials. The highest peak trunk extension angle (averaged across trials) was found during the HIGH trials for 64% of participants, and the least amount of trunk extension was found during the LOW trials for 93% of participants. All trials were graded as "Easy", "Very easy", or "Extremely easy" by all participants, except one set of HIGH and one set of MIDDLE trials that were graded as "A little difficult". Mild pain was reported by 1, 2, and 3 participants during the HIGH, MIDDLE, and LOW trials, respectively.

Discussion and Conclusions: The results indicate that it might be beneficial for people who are lumbar flexion-intolerant to avoid looking down during sit-to-stand transitions as this seems to increase trunk flexion. Similarly, people who find excessive extension of the spine painful could avoid keeping their gaze too high when standing up from a chair to reduce the amount of trunk extension. These findings will need to be further investigated in our low back pain population.

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THE APPLICATION OF MARKERLESS TECHNOLOGY AND DEEP LEARNING FOR THE ASSESSMENT OF SPINE MOVEMENT PATTERNS AND DYSFUNCTION

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Introduction: Clinical assessments used to identify abnormal spine movement patterns and dysfunctions are subjective and have issues related to reliability [1]. The current gold-standard for objectively assessing movement patterns is markered motion capture, which is infeasible for routine clinical use [2]. Therefore, the development of markerless motion capture approaches deployed on modern smartphone technology would be beneficial, as these approaches could be used in clinical settings. The overarching aim of this project is to develop and validate markerless approaches to perform static and dynamic spine assessment using depth cameras. Two use cases are provided that evaluate the use of depth cameras and deep learning to: 1) assess spine range of motion (Case 1), and 2) classify Adolescent Idiopathic Scoliosis (AIS; Case 2).

Methods: Case 1: Fifteen healthy male participants were recruited to develop a convolutional neural network (CNN) that uses depth data streams to segment the regions of the back and measure three-dimensional spine angles during repetitive forward bending. Two sets of forward bending trials were performed: the first with drawn on point markers and the second without markers. Markerless trials were used to assess model generalizability. The marked participant trials were separated into train and test datasets with an 80:20 split. Data from 5 participants were used to create a validation dataset, where participants performed the markerless protocol in addition to a trial with optical marker clusters (Vicon, Oxford, UK). Case 2: Thirty-three adolescents, both with and without AIS, were recruited from the Children's Hospital of Eastern Ontario. Participants were imaged in upright standing and forward bending positions with a depth camera. The participant images were divided into train and test datasets with an 80:20 split. A CNN-backed decision tree was trained to classify participant images (AIS or control). The algorithm was trained with both Colour images and Colourized depth sources.

Results: Case 1: Low RMSE (0.962- 3.938°) and strong ICCs (0.862-0.983) were found between markered and markerless systems in the primary movement axis. Case 2: The algorithm trained with Colourized depth bending images had the best performance when classifying AIS (accuracy=93%; specificity=75%; and sensitivity=99%). All other models had accuracies ranging from 70-93%.

Discussion and Conclusions: These results demonstrate the feasibility of using depth cameras to perform spinal assessments and measure spine kinematics without the use of markers.

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VALIDATION OF A MUSCULOSKELETAL MODEL TO INVESTIGATE HIP JOINT MECHANICS IN RESPONSE TO DYNAMIC MULTIPLANAR TASKS

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Introduction: Musculoskeletal (MSK) models provide a powerful tool to quantify hip contact forces (HCFs) and muscle activations using non-invasive data collection. However, existing MSK models are limited by the hip range of motion or the degree of hip musculature detail.[1,2] Therefore, the purposes of this study were to: i) modify the existing 2396Hip MSK model[1] to simulate dynamic multiplanar tasks; and ii) to validate the modified MSK model against experimental data.

Methods: The MSK model was modified to increase maximum hip and knee motion while maintaining physiological muscle moment arms.[2] Motion data, ground reaction forces (GRFs), and electromyography (EMG) were collected for five healthy adults (mean age = 25 [6] years, two females) during eight tasks (Figure 1). The motion and GRF data were input into OpenSim[3] to calculate muscle activations and HCFs. *Z*-scores were calculated to compare the participants' modeled HCFs with previously-reported experimental HCFs measured using an instrumented hip prostheses in total hip arthroplasty patients (age range = 50-68 years). A cross-correlation function was used to calculate the relationship between the modeled and experimental muscle activations.

Results: The modeled peak resultant HCFs were, on average, 2.3-6.5 SDs higher than the experimental HCFs. The correlation coefficients indicated strong relationships (≥ 0.75) between experimental and modeled muscle activations in 50 of the 56 comparisons (Table 1).

Discussion and Conclusions: The HCFs quantified in these young adults were greater than two SDs higher than the HCFs previously measured *in vivo* due to the movement differences in these populations. This study suggests that the new model is an appropriate method to quantify HCFs and muscle activations in response to dynamic, multiplanar tasks among young, healthy adults.

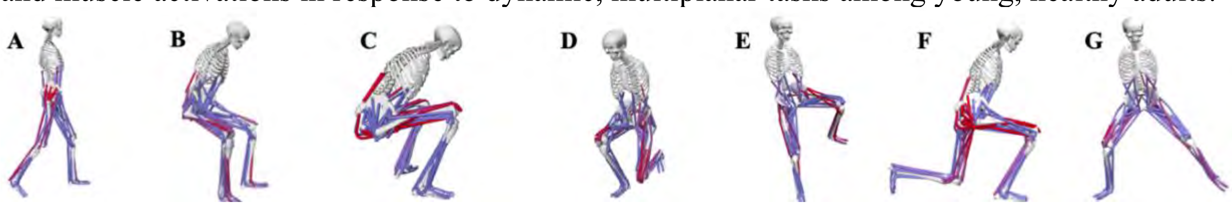

Figure 1: A) gait, B) sit-stand/stand-sit; C) squat; D) split squat; E) hurdle step; F) lunge; G) lateral squat walk.

Table 1: Group mean (SD) cross-correlation coefficients comparing modeled and experimental muscle activations.

Movement	GMax	GMed	TFL	AMag	RAbd	EObl	IObl
Gait	0.92 (0.07)	0.96 (0.05)	0.96 (0.03)	0.94 (0.07)	0.93 (0.05)	0.92 (0.05)	0.87 (0.10)
Stand-Sit	0.86 (0.08)	0.96 (0.03)	0.78 (0.16)	0.79 (0.17)	0.90 (0.06)	0.93 (0.06)	0.89 (0.09)
Sit-Stand	0.92 (0.06)	0.95 (0.02)	**0.67 (0.18)**	0.87 (0.10)	0.90 (0.10)	0.94 (0.04)	0.91 (0.08)
Deep Squat	0.76 (0.13)	0.75 (0.18)	**0.72 (0.25)**	0.83 (0.11)	0.92 (0.04)	0.92 (0.04)	0.80 (0.10)
Split Squat	0.83 (0.09)	0.94 (0.03)	0.81 (0.13)	**0.72 (0.22)**	0.93 (0.06)	0.94 (0.02)	0.80 (0.09)
Hurdle Step	0.93 (0.03)	0.89 (0.05)	0.83 (0.06)	0.89 (0.02)	0.94 (0.03)	0.85 (0.09)	0.75 (0.13)
Lunge	0.86 (0.09)	0.85 (0.05)	**0.63 (0.18)**	0.86 (0.11)	0.88 (0.05)	0.86 (0.14)	0.85 (0.05)
Lat. Squat Walk	0.86 (0.06)	**0.66 (0.14)**	**0.74 (0.10)**	0.80 (0.06)	0.95 (0.04)	0.86 (0.06)	0.86 (0.02)

Non-bolded values indicate strong relationships. Bold indicated moderate to good relationship. Lat: lateral.

IMPACT OF LOW-INTENSITY MUSCLE FATIGUE ON FINE MOTOR PERFORMANCE OF THE DISTAL UPPER EXTREMITY

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Introduction: With the rise in popularity of video games and esports, it has become increasingly important to understand the physical impact playing video games may have on the musculoskeletal system. Research has demonstrated the substantial negative impact that muscle fatigue has on various aspects of fine motor performance [1]. However, the intensities used to fatigue participants in these studies have not reflected those experienced by individuals playing video games. Gaming involves relatively low force production for extended periods of time [2]. Therefore, the purpose of this study was to determine if a prolonged, low-intensity fatiguing protocol causes muscle fatigue in the forearm and if any performance impairments occur as a result.

Methods: Twenty participants were recruited for this study (7F, 13M). Participants were separated into gamers and non-gamers. Surface electromyography was measured from seven muscles of the forearm and hand. The performance assessment involved hitting as many targets as possible during a 30-second mouse aiming task in an aim trainer (AimLab, State Space Labs, Inc., New York, USA). Reference contractions of finger flexion (30% max) were performed throughout the study to assess muscle fatigue. Participants also provided ratings of perceived fatigue (RPF) throughout the experiment. Following baseline performance and reference contractions, participants were fatigued by clicking a mouse at a set rate (5 clicks/second) for six, 10-minute bouts, with either the index or middle finger. Performance and muscle fatigue were assessed between bouts. Performance measures included targets hit, accuracy, precision, and error size. Mean power frequency (MnPF) and RMS amplitude were calculated during reference contractions.

Results: Gamers, on average, hit 13.8% more targets than non-gamers (Gamers: 66.30 ± 5.10; Non-gamers: 58.26 ± 5.41, $p= 0.001$). A 3.9% decrease in accuracy was observed following 10-minutes of clicking (Baseline: $84.21 \pm 7.17\%$, 10-minutes: $80.31 \pm 8.89\%$, $p=0.01$) and returned to baseline after 40-minutes of clicking. RPF significantly increased after the first fatiguing bout (Baseline: 0.54 ± 0.74; 10-Minutes: 2.68 ± 1.97, $p< 0.001$) and gradually increased with each 10-minutes of clicking (60-Minutes: 3.61 ± 2.17). Flexor digitorum superficialis (FDS) and flexor carpi ulnaris (FCU) showed significant increases in RMS amplitude during the fatiguing protocol ($p < 0.05$), by up to 35% and 17% of baseline for FDS and FCU, respectively. However, no changes were observed in MnPF.

Discussion and Conclusions: Accuracy displayed an approximately 4% decrease following the first bout of mouse clicking. However, this decline in accuracy did not result in any change to total targets hit throughout the 60 minutes. This may indicate a speed-accuracy trade-off, allowing participants to maintain performance by sacrificing accuracy. RPF values increased to a rating of 3.6/10 by the end of the experiment. RMS amplitude changes suggest FDS and FCU are the most fatigued muscles following mouse clicking.

References:

OPTOELECTRONIC MOTION CAPTURE PROTOCOL FOR IN-CLINIC ORTHOPAEDIC GAIT ANALYSIS

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Introduction: Optoelectronic motion capture has been used extensively in orthopaedic research to capture functional deficits during walking in patients before and after surgery. Despite significant research uptake, clinical translation of these tools has been poor as motion capture is typically done in specialized lab environments. However, this presents problems for patient access, data throughput, and participant recruitment and retention in research. Therefore, we aimed to implement a motion capture system in our orthopaedic clinic for ease of patient access.

Aim: Our objectives were to 1) design and install a motion capture setup and protocol in the orthopaedic clinic hallway for instrumented gait data collection, and 2) collect pilot kinematic gait data from patients before and after joint replacement surgery to demonstrate feasibility and preliminary validity of the setup.

Methods: We designed the system layout and installed a 14-camera optoelectronic motion capture system in the hallway of the orthopedic clinic within the constraints of a busy clinic environment and a hallway considerably narrower than typical motion capture labs. A novel retroreflective marker placement protocol was created to account for the suboptimal viewing volume and minimal sagittal plane viewing coverage. Patients participating in our RoboKnees randomized trial on robot-assisted knee replacement walked the length of the hallway five times at their self-selected walking speed pre-operatively, three months, six months, and 12 months post-operatively to assess gait changes over time. Three-dimensional lower extremity joint angles and stride characteristics were modeled from the motion capture data using Visual 3D.

Results: 16 participants scheduled for knee replacement participated in the gait analysis during their preoperative visit and at 3, 6, and 12 months postoperatively. Patients were on average 61 (±6) years old with a BMI of 35 (±8). Mean pre-operative walking speed was 0.94 (±0.14) m/s. 3D knee angle metrics were within variability limits of literature values from specialized gait labs on similar populations as seen in Table 1. This preliminary data demonstrates feasibility of our in-clinic motion capture setup.

Conclusion: We have designed and installed an optimized setup for instrumented gait analysis in an orthopaedic clinic hallway. Our results demonstrate feasibility and face validity. We will use the system for future studies assessing function before and after hip and knee replacement and other orthopaedic procedures.

Table 1: Knee Flexion Angles Compare to Literature Values

	Avg of Participants (±4.0)	Avg from Literature (±4.0)
1.Peak Knee Flexion during stance (°)	11.0 (±4.0)	8.0(±6.2)[1]
2. Peak stance phase adduction angle (°)	5.0(±5.3)	3.1(±4.3)[2]
3. Peak knee flexion angle during swing (°)	53.4(±7.7)	45.9(±15.4)[1]
4. Range of knee flexion (°)	48.4(±8.4)	49.9(±16.1)[1]

THE EFFECTS OF SUBCUTANEOUS FAT THICKNESS AND MUSCLE QUALITY ON THE AGREEMENT BETWEEN SURFACE AND INTRAMUSCULAR EMG

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School of Kinesiology and Health Sciences, York University, Toronto, ON

Introduction: Compared to intramuscular electromyography (iEMG), surface electromyography (sEMG) is a quick and non-invasive method for collecting muscle activity. Yet discrepancies between sEMG and iEMG signals have been identified and researchers have cautioned interpreting sEMG interchangeably with iEMG [1]. Subcutaneous fat thickness (SCFT) has been identified as a factor that may differentially affect sEMG and iEMG signal [2]. Recently, it was shown that increasing levels of intramuscular adipose tissue (IMAT) may reduce neuromuscular activation of the gluteus medius [3], suggesting that both subcutaneous and intramuscular fat may affect the sEMG-iEMG relationship. The purpose of this study was to investigate whether SCFT and/or muscle quality (IMAT) explain variance in sEMG and iEMG signal agreement.

Methods: This research is a secondary data analysis of 12 right-hand dominant adults (23.7±2.2y; 22.4±1.7kg/m^2) with no recent history of shoulder or back injuries. SCFT and IMAT were assessed in four locations (supraspinatus; infraspinatus; and erector spinae at the 4th and 9th thoracic vertebral levels) using a GE Logiq E r6 ultrasound system and 12 MHz linear array transducer (GE Medical Systems, Milwaukee, WI). Muscle activity was recorded at each location with surface and fine-wire electrodes using a Delsys Trigno® Research+ System (Delsys Inc., Natick, MA). Participants completed a series of upper limb maximum voluntary isometric contractions (MVIC) to elicit maximum contractile activity of the four muscles of interest. Participants then completed submaximal exertions at 30% MVIC. sEMG and iEMG signals will be linear enveloped and normalized to MVICs, following which the difference between signals will be calculated. Both musculoskeletal morphology parameters (IMAT, SCFT) will be measured from ultrasound images using ImageJ. IMAT will be estimated by calculating the greyscale value (0-255) of the muscle region, where a higher value reflects a greater amount of non-lean tissue [4]. SCFT will be estimated by measuring the superficial and deep borders the tissue at the midpoint and lateral image points. A linear regression will be conducted to determine whether the difference between sEMG and iEMG signals can be predicted by morphology factors (SCFT and IMAT).

Expected results: Previous studies have shown that increasing levels of SCFT thickness can result in significant attenuation of sEMG signal amplitude [5]. We expect that lower muscle quality may further attenuate sEMG. Thus, we expect that both muscle thickness and IMAT will explain a significant amount of variance in the agreement between sEMG and iEMG with poorer agreement related to greater SCFT thickness and lower muscle quality (higher IMAT).

References

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[5] Kuiken TA et al. (2003). *Prosthet Orthot Int*, *27*(1), 48-54.

COMPRESSION INDUCED MICROINJURY PATTERNS IN THE SPINAL ENDPLATE

Jackie D. Zehr, Joe Quadrilatero, Jack P. Callaghan

Department of Kinesiology, University of Waterloo, Waterloo, ON

Introduction: The cartilaginous endplate aids in load transfer through the vertebral column [1] and regulates nutrient diffusion into the adjacent intervertebral disc [2]. Despite its functional and physiological relevance, little is known on how parameters of acute and/or prolonged compression loading mediate the pathway of endplate injuries. Exploring this knowledge gap may provide important insight into the microstructural and biochemical cascade that precedes macroscopic injury events. Therefore, this *in vitro* study investigated the incidence and distribution of microstructural endplate injuries associated with cyclic compression parameters.

Methods: One hundred and fourteen porcine cervical spinal units were included. Cyclic compression testing was performed with a servo-hydraulic materials testing system and protocols differed by posture (flexed, neutral), loading duration (1000, 3000, 5000 cycles), and peak compression variation (10%, 20%, 40%). Immunofluorescence staining for type I (i.e., subchondral bone) and type II (i.e., cartilage endplate) collagen [3] was performed to examine loading induced microstructural injury patterns. From the 678 acquired images, the incidence of node, avulsion, cartilage microfracture, and circumferential pore microinjuries were determined. The distribution of microinjuries between postures, spinal levels, and vertebrae were evaluated using chi-squared statistics and the association of lesion size with loading duration and loading variation was examined via linear regression.

Results: The incidence of each microinjury pattern is presented in Figure 1. The distribution of node (90%, $p < 0.001$) and avulsion (100%, $p < 0.001$) microinjuries was greater in flexed postures, while the distribution of cartilage microfractures was greater in neutral postures (82%, $p < 0.001$). Loading duration was significantly associated with lesion size ($p \leq 0.003$), but no significant relationships were observed for loading variation ($p \geq 0.222$).

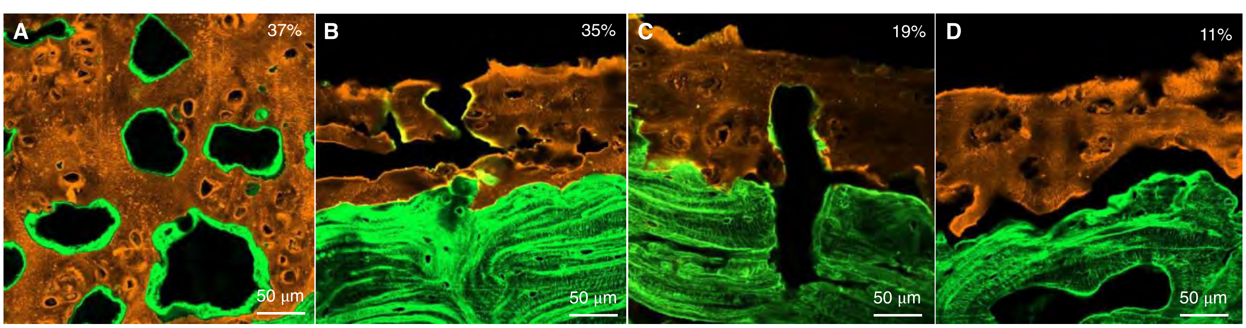

Figure 1. Representative images of circumferential pore (A), cartilage microfracture (B), node (C), and avulsion (D) microinjuries.

Discussion and Conclusions: Joint posture did not appreciably affect the incidence of endplate microinjury. However, microinjury patterns were differently distributed between flexed and neutral postures. The progression of lesion size was strongly influenced by the duration of compression loading.

References:

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Poster Session A – AHS Foyer Tues May 9 7:50 PM-8:50 PM		
1	Ikeade Adeyinka University of Toronto	Association Of Malaignment On Cartilage Wear
2	Benjamin Allen Ontario Tech University	Estimating Effort Durations For Common Automotive Manufacturing Tasks
3	Richard Barina University of Waterloo	Topology Optimization Of Spinal Implants Under Physiologic Loads
4	Daniel Beshay University of Waterloo	Proximal Humerus Fracture Testing
5	Anita Borhani University of Toronto	Racial Differeces In Lower Extremity Kinematics
6	Kristen De Melo University of Guelph	Optic Flow Influence On Muscle Activity In The Absence Of Movement In Different Body Positions
7	Kyle Farwell University of Toronto	Should Spine Motion Be Constrained While Stretching The Hip?
8	Randa Mudathir Western University	Four-Dimensional Ultrasound For Assessing Ligament Laxity In Thumb Osteoarhritis Patients
9	Kate Posluszny University of Waterloo	Efficacy Of Portable Lift Assist Devices For Paramedics
10	Aryen Shakib McMaster University	Numeric Validation Of Thoracic Blunt Ballistic Trauma In Human Body Models
11	Kim Stroesser University of Windsor	Injuries In Adult Pickelball Players.
12	Tiffany Tiu University of Toronto	Objective Validation Of A Novel Star Excursion Test
13	Kristin Yates University of Guelph	Adjustable Table Height For Cooking
14	Gokhan Bozyigit Brock University	Key Performance Indicators During 50 And 100 Meter Swim Lengths Across Four Swim Strokes
15	Josh Briar University of Guelph	Intervertebral Disc Pathology And Muscle Function
16	Calaina Brooke Wilfrid Laurier University	Balance After Concussion In Response To Perturbations
17	Hannah Coyle-Asbil University of Guelph	Wearables To Estimate The Energy Expenditure Of Preschool-Aged Children
18	Cole Dennis McMaster University	Characterization Of Soft Tissues And Their Role In Impact Attenuation For Injury Assessment Applications
19	Emma Donnelly Western University	Comparing Laxity In Robotic-Assisted And Conventional Total Knee Arthroplasty To Intact Knees
20	Lynton Lam	Sport Participation And Balance

	University of Guelph	
21	Cameron Lang Brock University	Work From Home Computer Workstations
22	Nigel Majoni McMaster University	Markerless Motion Capture For The Hands And Fingers
23	Alexandre Mir-Orefice University of Ottawa	Smart Insole Validation
24	Elizabeth Norman Western University	Comparison Of Muscle Forces During Active Flexion-Extension Motion Of The Wrist Before And After Total Wrist Arthroplasty
25	Kayla Russell-Bertucci University of Waterloo	Characterizing Surface Electromyography Muscle Activity And Upper Arm Kinematics In Video Game Players
26	Aliza Siebenaller University of Guelph	Spinal Deformity And Muscle Degeneration
27	Pratham Singh University of Toronto	Testing Environment Effects On Lower Extremity Kinematics
28	Sabrina Sinopoli Wilfrid Laurier University	Inflammation's Effect On The Annulus Fibrosus
29	Shahla Ziamanesh Nipissing University	Hand Transmitted Vibration During Impact Wrench Use
30	Dan Anzovino Brock University	Subthreshold Vibration And Standing Balance
31	Jessa Buchman-Pearle University of Waterloo	The Association Between Lateral Asymmetries And Low Back Pain
32	Miguel Corrales University of Waterloo	Comparison of Young and Older Adult Small Stature Female Rib Fracture in Side Impacts of Varying Velocities
33	Jessica Flammia University of Windsor	A Descriptive Analysis Of The Upper Body Kinematics Of Conductors
34	Donna Fok University of Waterloo	Low Back Responses To Running Shoe Midsole Cushioning
35	James Hunter Western University	Age-Related Differences In Glenohumeral And Scapulothoracic Kinematics Using 4dct
36	Hannah McMaster Brock University	The Role Of Diurnal Variation In Standing Low Back Discomfort
37	Andra Neptune Wilfrid Laurier University	The Effect Of Cyclic Loading On The Annulus Fibrosus
38	Jarrett Norrie Brock University	Automated Golf Performance Assessment Using Markerless Motion Capture Derived From A Cell Phone Camera
39	Behzad Danaei University of Waterloo	Dynamic Simulation Approach For Acetabular Cup Orientation Optimization
40	Isaac Seabrook Brock University	Effects Of Theraband Resistance On Sagittal Plane Kinematics Of The Back Squat
41	Tushar Sharma	Skin Input Persistent Inward Current

	University of Guelph	
42	Gillian Slade Ontario Tech University	Assessing The Reliability Of Maximum Voluntary Contraction Protocols
43	David Varandas University of Waterloo	Peak Flexion Moments During Squat, Stoop, And Straddle Lifts
44	Aidan Abraham McMaster University	Relationship Between Energy Absorption And Meniscal Function During Dynamic Knee Movement In Pediatric Patients With Acl Tear
45	Taylor Carson University of Ottawa	Isometric And Isokinetic Torque In Acl Defficient Adolescents With And Without Meniscal Tears
46	Alexandre Galley Western University	A Comparison Of Driving Vs Non-Driving Muscle Forces On A Novel Muscle Actuator System
47	Meghan Hanton-Fong University of Waterloo	Investigating The Repeatability Of Compensatory Movements In Rotator Cuff Tears To Improve Wearable Device Tracking
48	Madi Hunter Brock University	Adaptive Robotics For Wrist Rehabilitation
49	Adam Kapasi University of Guelph	Abductor Hallucis Cutaneous Reflex
50	Kristie Liu University of Toronto	Comparison Of Lower Limb Kinematics Between Marker-Based And Markerless Motion Capture
51	Sophia Nikitin Brock University	Forearm Muscle Fatigue During Computer Mouse Tasks
52	Grace O'Neill Nipissing University	Relationships Between Kinematic And Performance Variability During Obstacle Crossing
53	Nathan Oliphant McMaster University	Reliability Of The Opencap System For Determining Knee Kinematics During Single And Double Leg Rebound Jumps
54	Dilaver Singh University of Waterloo	Comparing Global And Local Response Of The Lungs In Impact Human Body Models
55	Brendan Pinto University of Waterloo	Effects Of Trunk Posture On Lifting Strength
56	Danielle Carnegie University of Toronto	Kinetic Adaptations To Restricting Spine Motion During Lifting
57	Sukirat Bhullar University of Waterloo	Shear Wave Elastography To Estimate The Mechanical Properties Of Soft Tissues

ASSOCIATION OF PATIENT CHARACTERISTICS, ANATOMY, AMD MECHANICAL ALIGNMENT WITH CARTILAGE WEAR PATTERNS IN MEDIAL COMPARTMENT OSTEOARTHRITIS

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Introduction: 6 million Canadians are currently living with Osteoarthritis (OA), resulting in chronic joint pain and loss of mobility. While OA can affect any of the body's joints, it is most commonly diagnosed in the knees and hips [3]. While knee OA (KOA) is multifactorial [1,2,4], mal-alignment of the tibia and femur appears to be present in the majority of OA cases; specifically, varus mal-alignment. Varus mal-alignment shifts the weight-bearing line onto the medial compartment cartilage, creating disproportionate loading patterns and accelerated cartilage degeneration. There is limited information in relation to how the mechanical and patient variables affect specific cartilage wear patterns in the knee. While satisfactory clinical outcomes have been achieved using joint-preserving surgical re-alignment, the limited understanding of the biomechanical etiology of KOA, continues to contribute to sub-optimal outcomes in some patients.

Aim: to determine the association between individual patient characteristics, knee alignment, and bone shape with cartilage wear patterns in patients with medial compartment KOA.

Methods: This is a retrospective study analyzing the MRI scans of 100 patients that were diagnosed with uni-compartmental OA within the last five years. Patients who were between the age of 30 and 70 years old and who were indicated for and received an HTO were included in the study. Demographic data including sex, age, height, weight, BMI, activity level, smoker/non-smoker, co-morbidities, osteoarthritis diagnosis (Kellgren Lawrence score), and tibial-femoral alignment will be extracted from patient charts. The de-identified MRI scans will be analyzed using medical imaging analysis software 3D slicer. The bone geometry of the tibia and femur will be segmented, and anatomical measures will be taken within the software. The cartilage in the knee will be segmented from the surrounding bone, and thickness maps of the cartilage will be created. Multi-variate linear regression analysis will be performed to determine which patient and anatomical variables best predict the location and severity of cartilage wear in medial compartment OA patients eligible for an osteotomy.

Expected Results: This study will provide clinicians with valuable information related to which patients are best indicated for a realignment osteotomy. Optimizing patient selection will result in better clinical outcomes for osteotomy patients. Ultimately, this research will improve long-term patient outcomes and will help reduce the burden on a healthcare system that is currently overloaded with OA cases.

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ESTIMATING EFFORT DURATIONS FOR COMMON AUTOMOTIVE MANUFACTURING TASKS

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Introduction: Evaluating the demands of upper extremity tasks is an important focus within automotive manufacturing ergonomics to help limit musculoskeletal injuries. Due to the cyclic and repetitive nature of these tasks, approaches such as the Maximal Acceptable Effort (MAE) equation [1] are used to estimate acceptable task demands that limit muscle fatigue development. Though the frequency and force requirements of the task are more easily obtained for these analyses, knowledge of the specific effort durations are much more difficult to measure precisely, and small discrepancies can have a large influence on the recommended acceptable forces.

Aim: The purpose of the proposed research is to: 1) develop a method to reliably measure precise effort durations in the field, and 2) develop a library of standardized effort durations for the most common automotive assembly tasks (e.g., pushing on a hose or mating a wire harness).

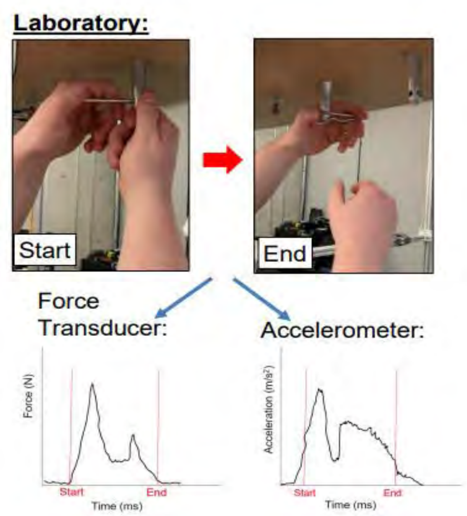

Figure 1: Hand-based task with corresponding force- and acceleration-time profiles. Key events will be determined to predict effort duration.

Methods: Laboratory testing will focus on 20 participants (10M, 10F) recruited from the university population who will perform 12 tasks requiring manual force exertions. These candidate tasks will be selected in consultation with industrial partners, based on need, and meeting the following criteria: (1) must be a manual hand-force exertion, (2) visibility of hand for video recording, and (3) must be a single action (e.g. push or pull). Tasks will be replicated in the laboratory by conducting at least 50 trials with a custom apparatus mounted to a force transducer. Additionally, a hand mounted accelerometer and a HD-video camera will be used to evaluate the feasibility of predicting effort duration in the absence of any force time-series data.

Expected Results: Based on the previous literature [2], we anticipate that each candidate task will have a unique effort duration value that can reliably be measured in the lab. By providing a library of effort durations that ergonomists can select from in their task evaluations, this work will hopefully help solidify maximum acceptable force recommendations in automotive manufacturing.

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TOPOLOGY OPTIMIZATION OF SPINAL IMPLANTS UNDER PHYSIOLOGIC LOADS

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Introduction: Instrumented spinal fusion using metallic implants is a common surgical procedure to stabilize the spinal column following injury and disease; however, high implant stiffness can cause improper load sharing resulting in adjacent segment degeneration [1]. Metal additive manufacturing (AM) offers the potential to address this challenge using topology optimization (TO) to reduce implant stiffness. The goal of this study was to compare single versus multi-objective TO design strategies for spinal implants under physiologic loading.

Methods: Physiologic loads to establish the boundary conditions for implant TO under axial and multi-axial loading (Table 1) were obtained from instrumented vertebral body replacements for flexion activities from the OrthoLoad online database [2]. Interbody cage implants with dimensions of 11Hx12Wx16L mm were then created for the available design space. Altair Inspire™ and nTopology were used to perform single-objective (mass minimization with a safety-factor) and multi-objective (stress and displacement minimization) TO of the design space established between the two endplate surfaces. Deformation and stress analysis compared axial and multi-axial loading scenarios.

Results: Single and multi-objective TO both produced tree-like implant designs with a small amount of compliance while keeping internal stresses low and adhering to AM feature size constraints (Fig. 1). The multi-axial load case required larger diagonal struts compared to the axial case, likely to account for the added bending and shear loads on the implant. Multi-objective optimization produced thicker conically oriented struts, with more branches than the single-objective optimization.

Discussion: This is a first attempt and concept to look at improving spinal implant designs using different TO strategies. TO introduced organic branching structures to distribute axial loads, minimizing the stress and displacement of the superior endplate. New biomechanically informed design guidelines can be drawn from the results to improve future implant designs. The multi-axial case evaluated only one loading scenario (flexion) for one patient; future design work will examine TO results from multiple patients and loading conditions associated with daily activities.

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Figure 1: Computer-aided design results of the Axial, Multi-axial, and Multi-objective Topology Optimizations

Table 1: Axial and multi-axial spinal flexion loads synthesized from an OrthoLoad dataset patient

Load Case	Fx (N)	Fy (N)	Fz (N)	Mx (Nm)	My (Nm)	Mz (Nm)
Axial	0	0	-600	0	0	0

IMPROVED PROXIMAL HUMERUS FRACTURE MANAEGMENT THROUGH ADVANCED IMAGING AND BIOMECHANICAL TESTING

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Introduction: Proximal humerus fractures (PHFs) are identified as the second most common upper extremity fracture. Both health care costs being high and patient outcomes not being maximized arise from the repercussions of challenges and controversies in PHF management. To obtain more precise bone quantification and distinguish bone changes from those in the marrow, microCT and dual-energy QCT (DEQCT) has been suggested.[1,2,3,4] The objectives of this study are to: *i) create clinically relevant PHFs in cadaveric tissues; and ii) predict fracture characteristics using advanced imaging parameters under simulated fall conditions.*

Aim: This study aims to overcome the lack of quantitative data and understanding of parameters associated with common fracture patterns by developing advanced imaging techniques to optimize fracture evaluation in a cadaveric proximal humerus fracture model.

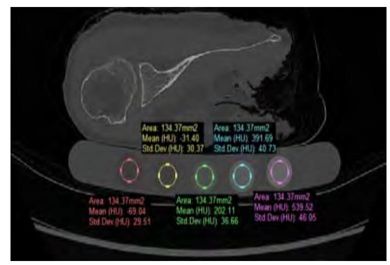

Figure 1: A clinical QCT scan of a cadaveric shoulder and calibration phantom with sampling of rods of known density.

Methods: 10 sets (left and right) of cadaveric shoulder specimens will undergo single- and dual-energy quantitative CT (QCT), DXA, and microCT imaging. Shoulders will be randomized to either impact or quasi-static biomechanical testing groups. Bone parameters from imaging will be used to determine predictive models of fracture location based on comparisons of bone in pre- and post-fracture scenarios.

Expected Results: We hypothesize that; *i) a clinically relevant complex PHF can be produced by quasi-static and impact biomechanical testing; ii) in comparison to single-energy QCT, DEQCT will provide stronger predictions of bone strength in the proximal humerus, and fracture location will be best predicted using microCT-based microstructure, and iii) CT parameters will be better predictors of fracture location than DXA-based aBMD or cortical thickness.* This study will be the first to use DEQCT and its parameters to evaluate PHFs, providing a first step in the clinical evaluation of this advanced imaging modality.

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Table 1: Current cadaveric donors age and sex

	Donor 1	Donor 2	Donor 3	Donor 4	Donor 5	Donor 6	Donor 7
Sex	M	F	F	F	F	M	M
Age	78	85	78	91	98	88	78

RACIAL DIFFERENCES IN BIOMECHANICAL OUTCOMES IN RESPONSE TO INJURY RISK ASSESSMENT TASKS

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Introduction: Several neuromuscular, biomechanical, and morphological variables have been identified as ACL injury risk factors. While individual participant variables such as age and sex are commonly considered in experimental designs, race has not been adequately considered in biomechanical research [1]. This is potentially problematic as research reports racial disparities in perioperative outcomes, knee morphological variables, gait parameters, and musculoskeletal injuries and symptom severity [1, 2, 3]. This suggests that BIPOC groups are under-represented in the normative neuromuscular and biomechanical benchmarks used to identify injury risk and evaluate return to activity, thus creating divisions in quality of care. Although recent evidence suggests differences in gait, running, and landing mechanics between African Americans and Caucasian Americans [1,], no other studies have explored biomechanical racial differences in functional tasks commonly used to assess injury risk and return to activity.

Aim: quantify biomechanical and morphological differences in Black Canadian (BC), Indigenous Canadian (IC), and Caucasian Canadian (CC) individuals.

Methods: Thirty participants will be recruited (10 BCs, 10 ICs, and 10 CCs). 3D kinematics and ground reaction forces will be collected while participants perform four tasks (walking, drop vertical jump, in-line lunge, and step-up). 3T-MRI scans of the knee will be obtained to quantify common knee morphological variables. Five participants from each group will be selected to develop participant-specific finite element models using the collected data. The pressure distribution across the articular surface and the stress and strain distribution through the tibia and femur will also be quantified. Statistical analyses will be performed to determine if there are statistical effects of race on biomechanical outcomes.

Expected Results: Studies report racial differences in posterior tibial slope and gait, running, and landing mechanics [1]. As such, it is expected that significant knee morphological and trunk and lower extremity biomechanical differences will be observed between BCs, ICs, and CCs in response to the four tasks in the current study. The results of this study will inform injury reduction and return to activity practices, improving the quality and equity of care in BIPOC groups.

References:

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THE ROLE OF OPTIC FLOW ON MUSCLE ACTIVITY IN THE ABSENCE OF OVERT MOVEMENT IN SEATED VERSUS STANDING POSITIONS

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Introduction: To fully understand human interaction and locomotor navigation strategies, we must model and explore interrelationships that exist between environments, tasks, and individuals [1,2]. With this advanced understanding, we may be able to predict and understand human motion in relation to the surroundings [1]. Perception-Action (P-A) literature has been pivotal to further our understanding of the innate relationship humans have with their environment. Perception and action systems have been proposed to evolve together in mammals not as discrete, independent constructs, but rather in a close interrelationship [1]. Much of the support for this theory has been derived from studies assessing newborn [e.g., 3] and infantile [e.g., 4] stages of development. While there is existing literature surrounding P-A coupling in adulthood [e.g., 5], the strength of the relationship requires further exploration. More specifically, an understanding of how P-A via vision can influence movement control on a neurological level (i.e., muscle activity) is required.

Aim: The purpose of this study is to examine the effects of virtual optic flow (i.e., pattern of motion of the environment caused by the movement between the observer and the visual scene) on muscle activity (via electromyography [EMG]) in seated versus standing positions.

Methods: Postural tasks will be completed by exposing participants to virtual optic flow (via computer screen) in a simple virtual environment (i.e., hallway), a mid-complexity virtual environment (i.e., grassy, uneven terrain), and a more complex one (i.e., undulating hill). Muscle activity of the major walking muscles (e.g. tibialis anterior, gastrocnemius, vastus medialis, and semitendinosus) in the right leg will be measured via EMG. Participants will be instructed to assume three positions: seated with feet planted, seated with feet dangling, and upright stance, to measure the influence of visual optic flow in the absence of whole-body movement.

Expected Results: It is hypothesized that experiencing dynamic visual information will result in greater muscle activation compared to baseline measures. Specifically, we predict that the onset of optic flow and the environmental cues expanding on the retina in the standing position will elicit pre-activation patterns in the lower limbs, as the visual flow information will mimic that typically encountered during forward walking [6]. In the seated position, it is likely that participants will show increased muscle activation above baseline, however, only at sub-threshold levels. Finally, we expect that participants will experience greater activation in the dangling legs position as there is less intersensory conflict. In general, seated positions are often associated with passive movement (e.g., sitting in a wheelchair) which would mediate the level of activation, but we expect increased activation as the visual system perceives a stimulus to be acted upon [3,4,5,6].

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SHOULD SPINE MOTION BE CONSTRAINED WHILE STRETCHING THE HIP? CONTRASTING THE ACUTE CHANGES IN SPINE FLEXION AND LOWER EXTREMITY KINEMATICS DURING A SQUATTING AND LIFTING TASK

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Introduction: Athletes' inability to adopt or maintain a neutral spine posture, perhaps because they lack sufficient active or passive hip flexion mobility, could lead to excessive use of spine flexion and an elevated risk of disc injury [1]. Accordingly, many advocate for neutral spine postures and hip dominant movement strategies while performing bilateral training exercises like squats and deadlifts [2]. However, to achieve this, large hip flexion ranges of motion (ROM) are needed. Hip flexion mobility training has been used to facilitate changes in passive hip flexion, although even substantial changes in ROM are not consistently reflected in functional tasks characteristic of sport [3]. One reason for this may be the lack of adjacent joint (lumbar spine) control while attempting to increase hip flexion mobility.

Aim: To examine the influence of an acute bout of hip flexion mobility with and without lumbar spine motion constrained, on spine flexion and lower extremity kinematics in a squatting and lifting task.

Methods: A randomized, cross-over within-subject study design. Approximately 20 participants will be recruited to participate in two collections, each of which will include hip flexion ROM testing and two 8-rep sets of squats and deadlifts (transfer tests) prior to and following one of two 15-minute hip flexion mobility interventions: (1) a supine straight leg raise with spine motion constrained; or (2) a seated sit and reach without spine motion constrained. Hip flexion ROM and ankle, knee, hip, and spine kinematics during the two transfer tests will be measured and compared at baseline, immediately post intervention, and 10-minutes post intervention).

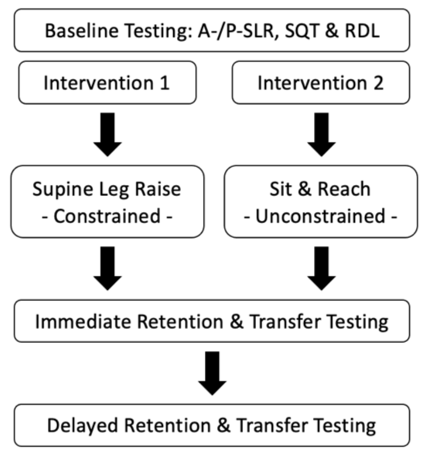

Figure 1: Proposed methodology. A-P-SLR = active / passive straight leg raise; SQT = kettlebell squat; RDL = Romanian deadlift.

Expected Results: An acute bout of hip flexion mobility training with spine motion constrained will increase the hip flexion ROM used during subsequent squatting and lifting exercises (i.e., positive transfer). This influence is expected to persist following 10 minutes of passive rest. However, the residual kinematic effects unclear. Examining athletes' spine curvature while performing transfer squatting and lifting exercises will yield insight into the acute influence of constraining lumbar spine motion during hip flexion mobility training, and thus, help guide the design and implementation of exercise, warm-up and recovery protocols.

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FOUR-DIMENSIONAL ULTRASOUND FOR ASSESSING LIGAMENT LAXITY IN THUMB OSTEOARHRITIS PATIENTS

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Introduction: Thumb osteoarthritis (OA) is the most common form of OA in the hand, disproportionately affecting more women than men [1]. Ligament laxity, or loosening, is thought to be a risk factor for thumb OA [1]. Computed tomography (CT) has been widely used to assess thumb joint morphology and biomechanics. However, CT imaging provides little information on the behavior of surrounding tissue structures such as the ligaments supporting the thumb joint. Therefore, developing an image-based approach to assess ligament laxity during thumb motion may provide clinicians with a tool to assess patients' predisposition to thumb OA.

Aim: The objective of this study is to develop a four-dimensional ultrasound system (4DUS) that collects 3D ultrasound images with time of the thumb joint and its surrounding ligaments during thumb motion.

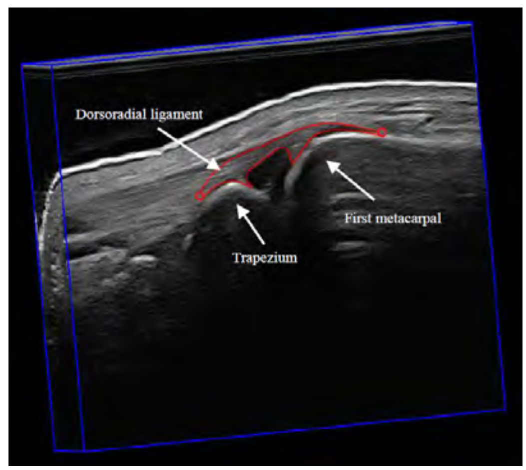

Figure 1: One 3D volume extracted from the 4DUS images depicting the thumb joint anatomy.

Methods: A 4DUS system consisting of a motorized semi-submerged transducer assembly was developed. A high frequency transducer was automatically translated 1-2 centimeters laterally back and forth along the location of the thumb joint. A healthy male and female participant were recruited to validate the 4DUS system's capability to resolve the ligaments surrounding the thumb joint during motion. Four-dimensional images of abduction of the thumb were collected from each participant. The 4D images were exported into 3D Slicer (Version 5.0.2, www.slicer.org), and the dorsoradial ligament was segmented from each 3D volume of the 4D images (Figure 1). Changes in ligament length throughout each motion were then calculated.

Expected Results: The segmentations of the dorsoradial ligament from the 4DUS scans indicate a decrease in ligament length throughout thumb abduction in both the male and female participants. Further results involve the use of this system on a cohort of healthy male and female participants as well as male and female OA patient to understand a) the patterns of ligament laxity associated with disease onset and progression and b) the patterns in ligament laxity predisposing women to thumb OA.

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THE EFFICACY OF PORTABLE LIFT ASSIST USE IN A PARAMEDIC SERVICE

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Introduction: Paramedics commonly perform lifts to provide the necessary medical attention to emergent and non-emergent patients. Patient dispositions (i.e., demographics, medical conditions, fall location, emergence) can complicate patient handling (including lifts), which can place paramedics at a higher risk of injury. Portable lift assist devices are used to reduce and/or eliminate the paramedics' biomechanical exposures associated with lifting patients.

Aim: To evaluate the efficacy, user perception, and biomechanical exposures associated with portable lift assist use in comparison to paramedics' care as usual (unassisted lift) to transfer a patient from the floor to a stretcher.

Methods: Twenty participants were recruited from a paramedic service. A cross-sectional within-subjects experimental design was used to investigate the effects of portable lift assist devices, including the Binder© (Binder Lift Inc., WY, USA) and the Eagle© (Manager International Ltd., Wales, UK). To assess the biomechanical exposures, surface electromyography was collected using Delsys© sensors (Delsys Inc., MA, USA) on the bilateral lumbar erector spinae. Amplitude probability distribution functions (APDFs) were developed to assess the proportion of peak (90th percentile) exposures experienced by the erectors when using portable lift assist devices (Figure 1). An exit interview identified the users' preferences and perceptions to evaluate device efficacy.

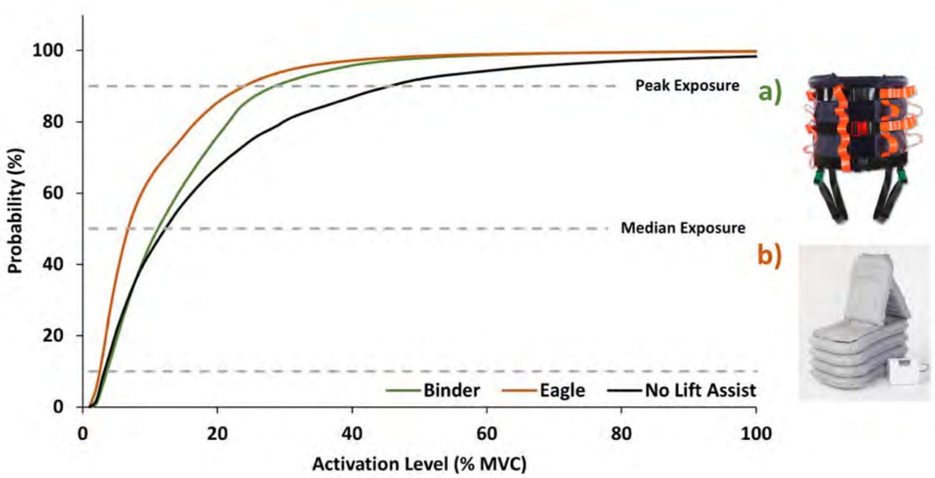

Figure 1: Preliminary APDF on exposures experienced by the right lumbar erector spinae when using a) the Binder©, b) the Eagle©, and no portable lift assist device when lifting a patient from the floor to a stretcher.

Expected Results: Relative to their maximum voluntary contractions, it is expected that participants would experience reduced erector exposures with the use of portable lift assist devices. While lift assists may reduce physical exposures, paramedics may resort to manual methods in emergent situations. Personal factors that would also influence lift assist use include experience/training, strength/size, confidence in lifting partner, injury concerns, and/or biohazard avoidance. Patient factors include comfort with lift decisions, patient conditions, biohazards, and their location. Overall, paramedics would prefer simpler and versatile systems with ease of use (i.e., Binder©), rather than devices with complex and increased components that may not be suitable for their working environments (i.e., Eagle©).

NUMERICAL VALIDATION OF THORACIC BLUNT BALLISTIC TRAUMA IN HUMAN BODY MODELS

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Introduction: Personal armor systems are worn by members of law enforcement and armed forces for protection against impacts. Soft body armor, made from layers of ballistic resistant fibers, is appealing due to its light weight; however, the fibres deform substantially under impact and can injure the wearer. Blunt traumas can occur as the back-face of the armor strikes the wearer, manifesting as bone fracture, organ injury, etc. Cadaveric experiments have been previously conducted [1, 2] to quantify the biomechanical response of the torso in these events but are limited in number. Human body models (*e.g.* the Total Human Model for Safety, THUMS, Toyota Central R&D Labs, Inc., Nagakute, Japan) numerically recreate the biomechanical behaviour of the human body during automotive crashes and could be a useful tool for investigation of injury from these events, if their response to this higher rate localized impact is realistic.

Aim: The purpose of this study was to evaluate the performance of the 50th percentile male THUMS V6.1 FE model under high-rate impacts in the thoracic region representative of that seen in blunt ballistic trauma.

Methods: Numerical recreation of previous cadaveric experiments was conducted using the LS-DYNA® solver (ANSYS, Inc., Canonsburg, United States). The location of impact was at the center of the sternum. Three unprotected tests were simulated: 1) a 140g baton at 20 m/s, a 140g baton at 40 m/s, and a 30g baton at 60 m/s [1], along with 4) a ballistic protected test (with soft body armour) [2]. Ultra-high-molecular weight polyethylene (UHMWPE) armor and a 7.62 NATO ball projectile (9.72g) were modelled using solid elements, with the armor modelled using multiple layers of sub laminates as an approximation of the overall composition.

Expected Results: Force, time, displacement and acceleration data will be gathered from the numerical models and compared to experimental results. Good correlation between numerical and experimental work will further validate the viability of the THUMS models for thoracic blunt ballistic applications.

Discussion: Human body models developed for automotive injury assessments need to be validated prior to use for blunt ballistic scenarios. While experimental data are limited, this study represents a robust evaluation of the biofidelity of this model. Once confirmed, investigations into the response of the thorax under high-rate impacts can be reliably conducted, particularly in regions where instrumentation is difficult, such as the lungs. Furthermore, next generation armors can be more readily assessed, where experimental validation has proven to be difficult.

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OCCURRENCE, PREVENTION AND TREATMENT OF PICKLEBALL INJURIES IN HEALTHY ADULTS

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Introduction: Pickleball, a paddle sport created in 1965, has grown tremendously in recent years [1]. Despite its popularity, there is little peer reviewed evidence regarding injury occurrence, prevention, or treatment of pickleball injuries [2]. Studies have examined the effects of participation on pickleball players [3], but there is a lack of information available to guide future research regarding injuries in the sport.

Aim: The aim of this research is to learn more about prevention strategies, treatment planning, and rehabilitation for pickleball injuries. By understanding the prevalence and severity of these injuries, and how these injuries occur, they may be managed more effectively.

Methods: A scoping review using the framework by Arksey and O' Malley [4] is underway to identify the gaps in the literature regarding the positive and negative effects of pickleball participation. Following this, an online survey will be conducted on an international scale to identify common injuries, mechanisms of injury, and strategies that pickleball players utilize to prevent injuries from occurring. Last, varsity athletes from various sports (softball, baseball, volleyball, basketball, soccer) will participate in a pickleball intervention aimed at improving off-season fitness and reducing skill degradation (e.g., reaction time, hand-eye coordination).

Expected Results: The review will identify gaps and establish the scope of the literature related to pickleball injuries. The survey will provide us with a wealth of current information to help us understand the injury trends, mechanisms, prevalence, and current treatment/management strategies for practicing pickleball players world-wide. It is hypothesized that a pickleball intervention for varsity athletes will result in an improvement in fitness and hand-eye coordination and reaction time in the off-season, while limiting injury potential.

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VALIDATING THE STAR BALANCE MAT AGAINST THE STAR EXCURSION BALANCE TEST

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Introduction: Assessment of lower extremity (LE) function is important for evaluating injury risk and post-injury functional outcomes in clinical and athletic settings. The Star Excursion Balance Test (SEBT) is a valid and reliable test for assessing left-to-right limb functional symmetry and readiness for return-to-play [1]. The test involves a star pattern taped on the floor and the participant maintains a single-leg stance in the centre of the star and reaches along the tape in each of the eight directions with the other leg to a maximal reach distance. However, the SEBT requires a large footprint and a burdensome setup. The Star Balance System (SBS), consisting of the SEBT printed onto a yoga mat, was developed to address these limitations. However, the SBS has not been validated.

Aim: i) assess the intra- and inter-rater reliability of SBS; ii) objectively validate the SBS by comparing kinematics between the systems.

Methods: Twenty healthy participants aged 18-35 were recruited. After a series of practice trials, participants performed the SEBT on both the traditional setting and the SBS (Figure 1). Two trials in each direction on both systems were performed in a pre-randomized sequence. Two raters each recorded the reach distances of all trials. An eight-camera motion tracking system (Theia Markerless Inc., ON, Canada) simultaneously recorded the participants' motions. Intra-class correlation (ICC) coefficients were calculated to determine intra-rater and inter-rater reliability. To determine the validity of the SBS compared to the traditional setting, a t-test and effect size analysis, Pearson's correlation analysis, and Bland Altman tests were performed. These tests were run separately for each of the reach directions on both systems. To compare the ratings of the SBS to the objective motion analysis derived distances, t-tests and effect size analysis, Pearson Correlation analysis, and Bland-Altman tests were performed. Currently, the motion capture data are being analysed.

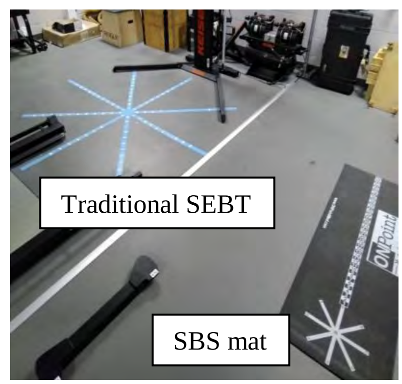

Figure 1: The experimental setup of the traditional SEBT and the SBS mat.

Expected Results: i) Intra- and inter-rater reliability of the SBS will be good to excellent; ii) clinical measurements with the SBS will be valid when compared to the traditional SEBT; and iii) the SBS will be valid compared to the traditional SEBT when using objective motion capture data

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WORKING AT STANDARD HEIGHT VERSUS AN ADJUSTABLE HEIGHT DURING A PRECISION, COOKING-SPECIFIC TASK: DOES IT MAKE A DIFFERENCE?

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Introduction: We, as humans, know that cooking is an essential part of life and it's not surprising that the restaurant industry in Canada brings in 79 billion dollars each year (1.5% gross domestic product) and employs 1.2 million people [1]. Food service work is considered a physically demanding job and as such, involves a risk to workers for developing musculoskeletal disorders. Food service workers often work long hours, spend nearly 100% of working time in prolonged standing, often in awkward and relatively static postures, and engage in repetitive movements, in a fast-paced environment, often without taking periodic breaks or a break in general [2]. In addition, cooks engage in a high level of task variety and are forced to work at a standard, non-adjustable height between 34-36 inches for most tasks. One of the principles of ergonomics suggests to "work at the proper height" which is dependent on the type of task (heavy, light, precision) being performed. Given that cooks will be of different body heights it is reasonable to wonder how working at a set table height may be affecting musculoskeletal health as well as workers' perception of their workstation and physical discomfort. A recent (2021) study using direct biomechanical methods to examine bakers in Iran, has specifically suggested that less prolonged neck flexion, less constrained trunk posture, and working at appropriate heights is recommended to reduce risks and suggests furthering the research by investigating muscle activity levels and their relation to posture of neck and back in bakers [3].

Aim: Investigate potential differences in perceived discomfort at multiple anatomical sites, muscle activity levels, and posture of the back and neck during a prolonged standing, cooking-specific task at the standard height versus an adjustable height, on separate visits.

Methods: Participants visit the lab on 2 days, separated by at least 1 week. Electromyography is recorded from cervical extensors at C4, thoracic erector spinae at T9, and lumbar erector spinae at L3. Relative angles are recorded via electromagnetic motion capture at the occipital protuberance and T2, T2 and T12, and T12 and S1. Perceived discomfort is measured at 6 anatomical sites using a visual analog scale. All measures are taken while performing a 1-hour simulated "cake-decorating" task. Day 2 differs with an option to adjust the table height every 10 minutes.

Results: It is hypothesized that participants will adjust the working table to a higher height when they are provided with this option, and that a reduction in perceived discomfort levels, muscle activity, and degree of cervical, thoracic, and lumbar flexion will be observed. In addition, we expect to see a positive correlation between participants' height and their chosen table height.

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KEY PERFORMANCE INDICATORS DURING 50 AND 100 METER SWIM LENGTHS ACROSS FOUR SWIM STROKES: A PRELIMINARY ANALYSIS

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Introduction: Key performance indicators (KPI's) are skill-based metrics used by coaches and athletes to adjust technique, track training, develop race strategies and predict performance times. The purpose of the study was to investigate the effect of swim-specific KPI's [stroke count (SC;#), stroke length (SL;cm), stroke rate (SR;#/s), and kick frequency (KF;#/s)] on total swim time (s) during 50m and 100m swim lengths across four swim strokes [butterfly, backstroke, breaststroke, and freestyle].

Methods: Varsity-caliber competitive swimmers (n=12 males; 20yrs) were recruited. Anthropometric measures including height (182.1cm), seated height (146cm), leg length (98.3cm), wingspan (191.1cm), hand length (20cm) and weight (80.2kg) were recorded. Shoulder and ankle range of motion (ROM) measurements were obtained, and a Y-balance test was conducted to profile the athlete's upper and lower limb mobility. Athletes completed four swim sessions consisting of a standardized warm up, 50m kick, 50m pull, 50m swim and 100m swim distances per stroke. KPI data was collected using a portable device (TritonWear, ON, Canada) secured inside the athletes' swim cap. TritonWear measures SC(#), SL(cm), SR(#/s) and total swim time (s). A GoPro Hero 6 (GoPro, California, USA) collected underwater video to facilitate calculating KF(#/s).

Results: Descriptives were calculated for all anthropometric, ROM and KPI variables across the two swim lengths and four swim strokes. Pearson product-moment correlations revealed significant relations between anthropometric measures and select KPI's; and between ROM measures and select KPI's ($p<0.05$) suggesting that both anthropometrics and ROM have the potential to influence swim technique and race strategies. A series of repeated-measures ANOVA's with Greenhouse-Geisser corrections revealed significant differences in select KPI's (SC, SL and KF) during the execution of 50m and 100m swim lengths across all of the four strokes ($p<0.05$), suggesting the technique employed by specific strokes had the potential to influence the KPI's per stroke. A series of repeated-measures ANOVA's with Greenhouse-Geisser corrections also revealed significant differences in select KPI's (SR, SL, KF) during the execution of 50m versus 100m swim lengths using butterfly, backstroke, breaststroke, and freestyle strokes ($p<0.05$), suggesting that swim length utilizes different KPI related strategies for strokes.

Discussion and Conclusions: Data-driven metrics obtained from portable instrumentation during swim performances facilitated understanding the relationship between anthropometrics, ROM and KPI's and how to adjust select KPI's relative to an athlete's anthropometrics, technique and race strategy across four different swim strokes and two swim lengths. These sport specific skill-based metrics can empower coaches and athletes to use KPI's to optimize athlete potential and target performance goals.

MUSCLE MECHANICAL PROPERTIES ASSOCIATED WITH INTERVERTEBRAL DISC PATHOLOGY IN A CANINE MODEL

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Introduction: Skeletal muscle has an exceptional capacity to remodel following an injury or in response to changes in its environment. The paraspinal musculature is responsible for generating and controlling movement of the spine. Previous work has highlighted inter-relationships between spine degeneration, specifically intervertebral disc (IVD) degeneration, and muscle mechanical properties [1]. Canines can be considered an ideal model for observing the relationship between muscle and IVD degeneration, as certain canine breeds commonly develop IVD degeneration and herniations that require surgical interventions [2]. Therefore, the purpose of the current work is to explore the influence of IVD degeneration on active and passive paraspinal muscle characteristics.

Aim: Development of a naturally developing model to identify the relationship between muscle functional changes and spine pathology.

Methods: Male and female dogs scheduled for surgery to treat IVD herniation will be recruited from the Ontario Veterinary Collage. Biopsies of parapsinal muscles (at the level of the IVD herniation) will be collected under anesthesia during surgery. MRIs will also be collected to measure muscle 'quality' via relative pixel intensity, the magnitude of IVD degeneration, and any associated spinal deformity present in each of the dogs.
Muscle biopsies will be chemically permeabilized. Bundles of fibres will be extracted and tested using a cumulative stretch-relaxation protocol to quantify passive mechanical characteristics. Single fibres will also be extracted and placed in a Ca2+ bath to elicit maximal activation followed by rapid shortening protocol to quantify active contractile characteristics.

Figure 1: The passive muscle testing apparatus.

Expected Results: It is expected that there will be a significant negative correlation between the magnitude of IVD degeneration and single muscle fibre contractile properties (maximal isometric stress and rate of force-redevelopment). Furthermore, it is expected that the passive muscle characteristics (stress and stiffness) will positively correlate with IVD degeneration, due to an increase in extracellular matrix (i.e. collagen) content. Overall, it is expected that the results will demonstrate that there are specific muscle changes associated with spinal degeneration which might present clinical targets for rehabilitation and surgical prehabilitation.

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BALANCE AFTER CONCUSSION IN RESPONSE TO VISUAL AND PHYSICAL PERTURBATIONS

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Introduction: Concussions are the most common type of brain injury with approximately 80% of cases presenting with balance impairments[1]. It has been demonstrated that concussion symptoms can lead to a lower health-related quality of life through the persisting cognitive, emotional, and/or physical repercussions[2]. Using current clinical assessments, balance deficits are said to recover within 3-7 days post-injury, however, research using complex visual environments and gait trials have shown impairments can last upwards of 30 days[3].

Aim: The aim of the current work is to observe how balance is affected after concussion in response to destabilizing physical and visual perturbations. A secondary aim is to observe if sex differences affect balance after concussion.

Methods: Subjects will be male and female between ages 18-40 recruited from the Hull Ellis Concussion Clinic, UHN Hospitals, and the University of Toronto St. George campus. The laboratory consists of a 6m x 3m moving platform, AMTI force plates, a 12 camera VICON motion tracking system, and an HTC Vive Pro Virtual Reality head-mounted display. The virtual environment that will be presented to the participant is a 'Dojo' room (Figure 1). There will be two blocks of trials including a standing and walking block. Participants will be presented with randomized physical and visual perturbations in the Anterior-Posterior (AP) and Medio-Lateral (ML) Directions. Outcome measures include: Centre of pressure (COP) max excursion, Centre of mass (COM) displacement and velocity, and Margin of stability (MOS).

Figure 1: Virtual 'Dojo' environment

Expected Results: It is hypothesized that concussed individuals will have increased instability in response to the visual and physical perturbations during standing and walking. This will be demonstrated by increases in COP max excursion during standing, increased COM displacement and velocity, and decreased MOS during walking. The use of visual and physical perturbations will challenge balance after concussion. Concussion symptomology can present differently in males and females, exploring this in balance and sensory integration will help in the design of rehabilitation programs after injury. Long term outcomes of this research could provide therapeutic information for the need to determine a subgroup of concussed individuals who may benefit from balance perturbation or sensory integration-based therapy.

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EXAMINING THE ABILITY OF WEARABLES TO ESTIMATE THE ENERGY EXPENDITURE OF CHILDREN AND IMPROVE DATA COMPATABILITY

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Introduction: To quantify the typical free-living energy expenditure (EE) of young children, research grade equipment needs to be portable, provide outcome measures in multiple planes of motion (linear and angular), be sensitive to changes in intensity, unobtrusive and capture data over extended periods of time. To achieve this long list, the output of wearable devices has been calibrated to criterion measures of EE (e.g., indirect calorimetry) [1]. A multitude of accelerometer brands have been designed for this purpose, however previous research indicates that not all brands are compatible [2], making it difficult to make cross study comparisons; correction factors are needed to address this issue. In addition to accelerometers, newer wearables often contain gyroscopes, which measure angular velocity and previous research suggests that inclusion of gyroscope data, improves EE estimates [3]. To our knowledge no calibration study has been performed in a free-living environment using devices with accelerometers and gyroscopes for a preschool aged population.

Aim: The objective of this *Study A* will be to use a hexapod robot to compare the raw output from different accelerometer brands and develop correction factors. The objective of *Study B* will be to determine whether combining gyroscope data and accelerometer data improves the accuracy of predicting the EE of young children.

Figure 1: Participant in monitor setup.

Methods: *Study A:* Six popular accelerometer brands/models, will be mounted to a hexapod robot. Oscillations ranging from 0.5 to 15 Hz will be introduced. Correction factors will then be developed via statistical analyses to determine data equivalency. *Study B:* Forty children (3-5 years) will be asked to wear a series of wearables on their hip, wrists, sternum, and back; their EE will simultaneously be captured via the Cosmed K5 portable metabolic system (Figure 1) while they move through a series of activity stations ranging from sedentary behaviors to moderate to vigorous activity. Predictive accuracy for EE will be compared amongst the accelerometer models using the i) accelerometer data, ii) gyroscope data, and iii) a combination of both sensors.

Expected Results: *Study A*: As previous research has shown, it is expected that the raw acceleration output obtained from the different brands/models will be significantly different and the use of correction factors will facilitate appropriate comparisons [2]. *Study B:* It is expected that the models created using both accelerometer and gyroscope data will have improved predictive accuracy for EE (compared to Cosmed measured EE) as both angular and linear motion will be captured [3].

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CHARACTERIZATION OF SOFT TISSUES AND THEIR ROLE IN IMPACT ATTENUATION FOR INJURY ASSESSMENT APPLICATIONS

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Introduction: The upper limb is vulnerable to injury in fields such as automotive, defence, or sports. These impacts may be blunt (over a large area, e.g. side airbag) or focal (concentrated, e.g. ballistic) and occur over a range of speeds. Injury risk in industry is typically assessed based on sensors in a metallic ‘skeleton’ of an Anthropomorphic Test Device (ATD, or ‘crash test dummy’). However, the loads measured will depend substantially on the impact attenuation properties of the soft tissue analogue used to transmit them (typically made of vinyl/foam composites). Very little is known about the impact response of natural soft tissue (adipose and muscle) [1] or this soft tissue analogue. Furthermore, few studies have investigated how the relative contributions of adipose and muscle may affect this attenuation, or how this may change with thickness (people of varying sizes and body types, of value for the development of an obese ATD).

Aim: The purpose of this study was to isolate soft tissue samples of varying compositions and thicknesses to characterize their material properties response under conditions representing focal and blunt impacts. These data will ultimately be used to establish criteria for future soft tissue representations in ATDs to ensure appropriate impact attenuation.

Methods: Soft tissue samples were extracted from eight cadaveric forearms, with samples taken from the anterior and posterior aspects midway along the length. Samples consisted of 8 mm diameter cores and 18x18 mm cubes, extracted using a coring tool and scalpel, respectively, 1.5 hours after removing from the freezer (to retain shape). Samples were measured with calipers to determine the % proportion of adipose and muscle tissue and in a few cases, samples consisted of entirely adipose or muscle tissue. Once thawed, indentation tests to 20% depth were conducted on the cubes to represent focal impacts using a 6 mm diameter indenter secured to an Electropuls E1000 (Instron, MA, United States) material testing machine at quasi-static ($0.001s^{-1}$) and moderate ($2s^{-1}$) strain rates. Core samples were tested in unconfined compression to 60% depth to represent blunt loading scenarios at the same strain rates. Finally, unconfined compression was conducted at high ($\sim 200s^{-1}$) strain rates using a custom-built twin guide wire drop tower. Data were combined to calculate the energy, hardness, and viscoelastic response of the tissues.

Expected Results: The coring tool was able to allow consistent preparation of samples during testing. It is expected that the variability of the muscle thickness will influence the mechanical properties of the soft tissues, whereas the proportion of adipose tissue will significantly affect the time-dependent viscoelastic response. This work will provide insight into the role of tissues in impact attenuation, and the material properties measured in this study will be compared in the future to a range of industrial materials to recommend the best flesh surrogate for future ATDs.

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COMPARING LAXITY IN ROBOTIC-ASSISTED AND CONVENTIONAL TOTAL KNEE ARTHROPLASTY TO INTACT KNEES

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Introduction: With the increasing popularity of robotic-assisted (RA) surgery in total knee arthroplasty (TKA), it is emerging as the superior method to achieve accurate component alignment over conventional methods [1-3]. However, how this translates to post-procedural knee joint kinematics remains to be investigated. This study aims to compare knee joints kinematics through laxity testing of TKA knees following RA and conventional TKA surgeries compared with intact knee kinematics. We hypothesize that RA TKA will more closely replicate the behavior of intact knees than those done using conventional TKA.

Methods: Six (6) paired knees and six (6) individual knees were used for this study. One knee of each pair underwent TKA surgery using conventional methods, while the contralateral side was done using a VELYS™ surgical robot (DePuy Synthes, IN, USA). Intact knees were not altered prior to mechanical testing. Each tested knee was mounted to a VIVO joint motion simulator (Advanced Mechanical Technologies Inc., MA, USA) for *in vitro* laxity testing. Each joint's baseline kinematics were collected while flexing and extending the knee between 15 and 90 degrees, under a compressive load of 30 N, but otherwise unconstrained. Laxity was assessed via applied isolated forces (anterior/ posterior (AP) force at 40 N and 80 N respectively) and torques (± 4 N/m internal/external (IE) rotation; ±8 N/m varus/valgus (VV)). Each test was performed at discrete knee flexion angles of 15, 30, 60 and 90 degrees. Results from the laxity tests were relative to joint behavior during baseline. Statistical comparisons were confined within each discrete flexion angle and degree of freedom. Laxity of intact, RA TKA and conventional TKA knees were compared in each degree of freedom via one-way ANOVAs and Tukey's post-hoc analysis, where appropriate.

Results: At 90° flexion, anterior translation was significantly different between groups (p=0.033), with conventional TKR knees exhibiting greater translation (9.3 mm ± 3.8 mm) than intact knees (4.4 mm ± 2.1 mm) (p=0.031). No other statistically significant differences were found.

Discussion and Conclusions: The results of the current study suggest that both conventional and RA TKA may result in comparable joint laxity to one another, as well as an intact – or healthy – knee. Conventional TKA may be the least effective in resisting anteriorly directed forces; however, it may be important to observe the total laxity envelope (i.e. AP translation as a whole) to observe whether differences in laxity, or lack thereof, are being compensated for in the opposite direction. These results could further inform TKA strategies for a given patient.

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DO COMPETITIVE SPORT PARTICIPANTS HAVE IMPROVED POSTURAL CONTROL?

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Introduction: All human movement ranging from complex athletic feats to simple acts of daily living depend upon postural stability. It follows then that balance itself improves along with any movement development, especially when demands are high as in competitive sport. How balance improves with sport participation likely depends on the principle of training specificity, that adaptations are related to the type of training performed [1]. This may account for limited evidence of enhanced postural control in athletes, in that most studies evaluated balance under non-specific and/or insufficiently challenging conditions (e.g. standing sway) [2]. The sport-stability relationship is further complicated by balance as a culmination of underlying dimensions (e.g. predictive & reactive control, sensory processing, speed & strength of postural movements), as well as by varying postural demands across sports (e.g. contact vs non-contact). Thus, conditions that pose greater challenge to specific aspects of postural control are needed to reveal and better understand any sport specific training effects on balance.

Aim: To determine if sport participants demonstrate improved balance under more challenging postural tasks, including resisting and recovering from external balance perturbations while performing manual tasks and under different conditions of sensory integration; as well as whether any sport-stability effects depend on contact vs non-contact participation.

Methods: Standing balance was perturbed via unpredictable support-surface translations; either rapid (~0.5 s) and scaled to evoke either feet-in-place (FIP) or stepping (STP) balance reactions; or oscillated as a continuous destabilization to postural sway (CON). STP trials included a follow-up perturbation (0.5 s delay) to assess anticipatory bracing of balance. FIP and CON trials included upper limb tasks of a point-on-target and ball-balancing to assess coordination with manual tasks. Eyes-open and -closed were done across all conditions to assess sensory adaptability, and quiet postural sway was included as a comparison to previous studies.
Comparisons in balance recovery and stability were made across non-sport (NonS) and sport athletes (S), subdivided as non-contact (S-NoC) and contact (S-C) sport participants in terms of postural resistance (induced postural motion), FIP & STP recovery (recovery time, degree of instability while recovering) and CON stabilization (stability margin).

Expected Results: Greater FIP and STP perturbation resistance and recovery is expected in S compared to NonS as reflected by improved response speed (onset, execution) and power (COP, step velocity). S-C will show an overall advantage in stabilizing against a follow-up perturbation. S may exhibit poorer stability in CON as a reflection of increased tolerance to postural instability, including a trade-off in postural stability to facilitate manual task performance. S will show enhanced sensory adaptability from practiced redirectment of visual resources (visual scanning). The degree of differentiation (% difference) among conditions across groups will provide an indication of underlying balance dimensions involved in sport-related postural stabilization.

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EFFECTS OF SPACE RESTRICTIONS ON UPPER EXTREMITY POSTURE AND MUSCLE ACTIVITY IN WORK FROM HOME COMPUTER WORKSTATIONS

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Introduction: Musculoskeletal Disorders (MSDs) are one of the most common types of workplace injuries within Ontario, accounting for 42% of all lost-time claims [1]. On average, people spend 37.5 hours a week on their computers and ~1800 hours annually of total screen time [2]. Spending >4 hours daily on a computer has been demonstrated to increase MSD risk including carpal tunnel syndrome [3,4]. With many workers transitioning to a work-from-home office scenario following the COVID-19 pandemic, many lack the resources to have a properly designed workstation, resulting in smaller, more confined workspaces; these may generate new occupational risk scenarios and currently lack information. The purpose of this work is to quantify the effects of computer workstations on upper extremity muscle activity and posture during computer tasks in restricted and unrestricted environments.

Methods: 40 university-aged participants (20 M, 20 F) with no history of upper limb injury or disorders will be recruited to complete typical computing tasks in restricted and unrestricted space scenarios. Participants will be outfitted with surface electromyography on 16 muscles of the trunk and right upper extremity (AMT-8, Bortec; sampled at 2048 Hz). Reflective motion capture markers will be used to evaluate posture of the participant sitting at a computer desk as they perform the protocol throughout each condition. Muscles of the right upper extremity will be normalized to muscle-specific maximums prior to collection. Participants will be asked to complete two computer mouse tasks using a computer program called AimLab. The first task is a point-and-click task, in which the participant clicks on the spherical targets as they appear in random order on the screen. The second task involves a mouse tracing task where the participant uses the mouse to follow the target on the screen as it moves in a randomized location. Both tasks will be completed in four mouse locations: 1) front edge of the desk, 2) the right-hand side of the table, 3) near the edge in front of the participant, and 4) deep on the desk of the right-hand side. All mouse locations will be completed in both restricted and unrestricted boundaries, for a total of 16 conditions. Muscle activation, participant posture, and computer performance will be evaluated during the tasks. Participants will report a rating of perceived effort after every trial. A two-way mixed model ANOVA examining four locations and a restricted or unrestricted setting ($p < 0.05$), with a between-subjects factor of males and females will be tested for significance.

Expected Results: We hypothesize that the addition of a space restriction will increase muscle activity and posture across all four mouse locations. Specifically, more distal regions will increase muscular activation of the forearm and shoulder. As well, an increase in shoulder abduction and neck flexion will occur in both later and far locations. Finally, the addition of space restrictions will elevate muscular requirements for all muscles involved.

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VALIDITY OF A MARKERLESS MOTION CAPTURE FOR THE HANDS AND FINGERS

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Introduction: We use our hands to interact with the external environment in our day-to-day lives, yet hand and finger movements are poorly represented in most biomechanical, clinical, and ergonomics assessments. Hand and finger postures and movement play important roles in the development of hand-related musculoskeletal disorders [1]. Optoelectronic marker-based motion capture is widely regarded as the "gold standard" for tracking segment and joint kinematics and has been effective in evaluating hand and finger kinematics [2]. However, marker-based systems are generally only useful in a laboratory setting and are impractical for real-world industrial applications. In recent years, advancements in markerless motion capture technology, using computer vision and neural networks, have shown great potential in overcoming the limitations of marker-based motion capture systems. However, current markerless systems primarily focus on whole-body motion and gait analysis, and have yet to be validated to track hand and finger kinematics. The development of markerless motion capture technology capable of measuring hand kinematics would significantly improve the ability to conduct clinical, ergonomic, and biomechanical assessments.

Aim: The aim of this study is to combine existing computer vision pipelines to develop and validate a markerless motion capture system to evaluate hand and finger kinematics.

Methods: Twenty participants will be recruited. The markerless motion capture system will be developed using MediaPipe Hands as its base pipeline, with a network trained on 21 landmark locations. Kinematics of the hands and fingers will be captured using both markerless and marker-based motion capture systems (Motion Analysis). The participants will be asked to complete four functional tasks for three trials each which include: i) typing a sentence, ii) an ordered method of building a Jenga tower, iii) performing one round of the peg test, and iv) performing a ratchet and bolt task. These tasks will be completed with Logitech C920e webcam cameras at 1m and 2 m distances from the collection space. Video key points will be taken from the markerless system and used as inputs into an OpenSim musculoskeletal model of the hand and wrist to compute hand and finger joint angles. Joint angles from the markerless motion capture will be compared directly to the marker-based motion capture to determine differences in joint angles between tasks, number of cameras used within our markerless system, and camera distances.

Expected Results: The validity of our markerless motion capture system will be evaluated in comparison to the conventional marker-based motion capture. The assessment will include calculating correlation coefficients (R^2), and root mean square error (RMSE) in joint angles between the markerless and marker-based motion capture systems. The R^2 and RMSE values will be calculated separately for each participant, task, and the number of cameras used. Developing a system that can track hand and finger kinematics will allow researchers to use it in many applications ranging from laboratory settings to real-world applications.

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VALIDATION OF INSTRUMENTED INSOLES FOR TEMPORAL GAIT ASSESSMENT

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Introduction: Gait impairment is a common symptom in people with multiple sclerosis (PwMS). In clinics, neurologists assess gait in PwMS through semi-subjective evaluations, which rely on visual inspections [1]; however, issues arise in terms of accuracy and reliability due to the nature of the evaluations and the time-interval between observations (6+ months). We are working towards developing an unobtrusive wearable solution for day-to-day in the wild gait monitoring for PwMS. Instrumented insoles (INS) provide a wearable alternative for objective assessment for use in the wild and in clinical settings [2]. However, the validity of INS needs to be established prior to their implementation in these settings. Recently, a markerless motion capture system (MoCap; Theia Markerless Inc. Ontario, Canada) was validated for gait kinematic analyses with high inter-session reliability and low variability ratios [3]. Therefore, the aim of this work is to validate the Neurogait 3.0 INS (Salted, Gyeonggi-do, South Korea) against the validated markerless MoCap system.

Methods: 10 healthy participants (4 female) performed 39 repetitions of a 6-metre overground walk. Their gait was recorded through the INS at 100 Hz via 6 pressure sensors, a triaxial accelerometer and gyroscope, and a markerless MoCap system collecting at 50 Hz. Gait events (i.e., heel strike and toe off) for the INS system were identified based on pressure thresholds using custom algorithms based on [4]. Gait events for the markerless system were identified using the "Automatic Gait Events" function in Visual 3D (C-Motion, Maryland, USA); they were visually inspected and adjusted as necessary. Temporal parameters were calculated for each system using custom algorithms. Two-way mixed, single score intraclass correlation coefficients (ICCs) were used to compare results between the INS and the markerless MoCap system.

Results: ICCs revealed an excellent (0.900 < ICC ≤ 1.000 [5]) positive inter-rater agreement between INS and markerless MoCap for temporal metrics (Table 1). Little variability is found between ICC results (Mean: 0.983; Standard deviation: 0.022; Range: 0.064). Further validation with marker-based optical motion capture and spatial metrics will be presented at the conference.

Table 1: Intraclass Correlation Coefficients comparing instrumented insoles and markerless.

Metric	ICC (3,1)	95% C.I.
Stride Time	0.999	[0.995, 1.000]
Stance Time	0.992	[0.970, 1.000]
Swing Time	0.984	[0.935, 0.995]
Single Support Time	0.982	[0.935, 1.000]
Double Support Time	0.935	[0.760, 0.980]
Step Time	0.999	[1.000, 1.000]
Cadence	0.989	[0.960, 1.000]

Discussion and Conclusions: The results show that temporal metrics calculated from the INS have excellent reliability relative to those calculated with the markerless MoCap system. These findings indicate high levels of correlation and agreement between systems and that INS are an appropriate tool for unobtrusive gait assessments and monitoring. The validation of INS enables the continuation of our work in creating an unobtrusive wearable solution for day-to-day in the wild gait monitoring for PwMS. Future work will aim to estimate spatial metrics from INS signals via machine learning using markerless MoCap as ground truth labels as well as assessing the reliability of our methodology using INS for gait assessments in PwMS.

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COMPARISON OF MUSCLE FORCES DURING ACTIVE FLEXION-EXTENSION MOTION OF THE WRIST BEFORE AND AFTER TOTAL WRIST ARTHROPLASTY: AN IN-VITRO CADAVERIC STUDY

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Background: Total wrist arthroplasty (TWA) implants are a surgical option for those suffering with end-stage wrist arthritis that aims to reduce pain and restore wrist function and range of motion. Multiple generations of wrist arthroplasties have been designed and implemented to reduce failure and increase longevity, however relatively high complication rates persist [1]. Furthermore, how TWA reconstruction affects wrist biomechanics, specifically the muscle forces required to actively flex and extend the wrist is currently not well understood. Therefore, the objective of this study was to ascertain and compare the muscle forces required to produce active flexion-extension motion for a series of cadaveric wrists in both the intact and TWA reconstructed states to gain a better understanding of how TWA alters the native biomechanical state.

Methods: A generic TWA implant based on current commercially available devices was designed and manufactured for in-vitro use. Six cadaveric upper limb specimens were acquired (mean age: 76±10 yrs) and the wrist extensors (extensor carpi radialis brevis (ECRB), extensor carpi radialis longus (ECRL), extensor carpi ulnaris (ECU)) and flexors (flexor carpi ulnaris (FCU), flexor carpi radialis (FCR)) were tagged. Pronation/supination motion was then restricted using a Steinmann pin and the arm was affixed to a previously validated active wrist motion simulator [2] that produced active motion via muscle forces controlled using wrist joint angle feedback. Active flexion-extension motion was then simulated from a minimum of 15 degrees of flexion to 15 degrees of extension while maintaining neutral radial-ulnar deviation, and the required muscle forces were recorded. Following this, the specimen was reconstructed with the custom TWA implant by an Orthopaedic Surgeon, and testing was repeated for the reconstructed state.

Results: In the intact state, the muscle forces required to achieve active motion from flexion to extension were up to 27N for the ECU and from extension to flexion up to 29N for the FCU. The reconstructed state required higher muscle forces for active motion from flexion to extension with a maximum of 54N for the ECU and remained largely unchanged from extension back to flexion with the FCU at 23N.

Discussion and Conclusions: The results of this work show that TWA reconstruction increases the extensor muscle forces required to actively move the wrist from flexion to extension compared to the intact state. This may have an impact on wrist biomechanics as well as the long-term fixation of the TWA implant components, which is known to be a complication of these procedures. Future work should investigate implant articular loading and implant-bone load transfer.

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CHARACTERIZING SURFACE ELECTROMYOGRAPHY MUSCLE ACTIVITY AND UPPER ARM KINEMATICS IN VIDEO GAME PLAYERS

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Introduction: Video game biomechanics is a growing field of interest, but with limited current knowledge. Office ergonomics research appears to be adjacent to video game ergonomics [1], as both examine interactions within a typically seated environment that includes a desk, computer, keyboard, and computer mouse as key features. However, playing video games across the range of casual levels to professional levels results in markedly different task intensities compared to common office tasks. Currently, only a few extant studies quantified muscle activity in different iterations of video gaming [2], however, the chosen muscles have limitations. Additionally, there is a lack of robust kinematic studies related to performing video game tasks. These gaps in task description and classification are gradually being addressed, however, fundamental questions regarding musculoskeletal exposures and their determinants are unresolved.

Aim: There were two aims: 1) to identify differences in muscle activity and kinematics in computer-mouse video game tasks between amateur and professional players, and 2) to compare baseline performance scores of professional and amateur video game players.

Methods: Right upper limb and torso kinematics will be captured using an optoelectronic VICON MX20 motion tracking system (VICON Motion system, Oxford, UK). Surface electromyography of wrist flexors, wrist extensors, elbow extensors, elbow flexors, rotator cuff, and prime movers of the shoulder will be measured on participant's right side with a Noraxon T2000 telemetered system (Noraxon Inc., Scottsdale, AZ, USA). Participants will perform maximal voluntary contractions for each of the chosen muscles prior to the task. The workspace will follow ergonomic guidelines to normalize set up configuration across participants. In game performance scores will be measured during seven two-minute repeated trials of the rhythm-based video game 'osu!'. Baseline performance tests will be administered to compare professional and amateur groups, and also to correlate with game performance scores. These baseline tests include the Purdue Pegboard (Layfayette Instrument, Layfayette, USA), an online Fitt's test (Cornell University, Ithaca, USA), and a reaction time test using a computer mouse.

Expected Results: We expect to identify the most active muscles during computer-mouse video game tasks. Additionally, the kinematics data will be used to group participants into whole-arm group and wrist-and-elbow dominant groups. These groups are expected to predominantly use the prime movers at the shoulder and rotator cuff or muscles that act at the wrist or elbow joints, respectively. Finally, we will be able to link baseline aptitudes to gaming performance metrics by comparing the baseline performance scores to game-based metrics for both our professional and amateur groups.

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EFFECTS OF GLYCEROL-INJECTED PARASPINAL MUSCLE DEGENERATION ON SPINAL DEFORMITY

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Introduction: Spinal deformity is often associated with paraspinal muscle dysfunction, though the cause remains unclear [1]. We have previously demonstrated that bilateral glycerol injections of the paraspinal muscles increases collagen deposition (fibrosis) and leads to kyphotic deformity [2]. Another study found that scoliotic curvatures can be manipulated by altering the collagen content of the paraspinal muscles and that more collagen was present on the concave side of the curvature [3]. This study aims to extend this by evaluating the effect of unilateral glycerol-induced muscle degeneration on spinal deformity. It was hypothesized that the glycerol injection would cause fibrosis and result in a spinal curvature to the ipsilateral side.

Methods: 36 C57BL/6 mice (Charles River Laboratories, Quebec, Canada) (18 male and female) were used in this study. 4 mice of each sex were used as controls and did not receive any injections. The remaining 28 mice received 4 injections, each 2 weeks apart, of either glycerol or saline (sham). Injections were done on the right side of the spine, along the length of the lumbar paraspinal muscles. Immediately post-sacrifice, imaging was performed with a Skyscan 1278 microCT (Bruker, Kontich, Belgium) to measure spinal deformity and muscle density. Half of the biopsies from the erector spinae and multifidus muscles were flash-frozen for muscle histology and the other half were permeabilized for mechanical fibre testing.

Results: No significant difference (p=0.4949) was found in coronal plane curvature (Cobb angles) between the control ($\bar{x}$= 39.8, ***SEM*** = 3.3), saline ($\bar{x}$ = 34.0, ***SEM*** = 3.0), and glycerol ($\bar{x}$ = 37.7, ***SEM*** = 3.3) groups or between sexes (p=0.3744), and no interaction was present (p=0.6151). Meaningful lateral deformities (> 20 degrees) were only observed in two mice, both in the glycerol injection group; the curvature was toward the side contralateral to the injection. Muscle density was evaluated as a ratio (right side:left side); a significant difference was found between groups (p<0.0001) but not sexes (p=0.3319), and no interaction was present (p=0.2531). Specifically, significant differences were found between the glycerol and saline group (p<0.0001) as well as the glycerol and control group (p=0.0059), but not between the saline and control group (p=0.4005). Results from muscle mechanics and histology are still to come.

Discussion and Conclusions: The glycerol injections did not cause spinal deformity as expected; current analyses are being done to quantify the magnitude of muscle degeneration caused by the glycerol injections. It is possible that not enough glycerol was injected, in these unilateral conditions, to cause sufficient paraspinal muscle degeneration to affect the spine.

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KINEMATIC COMPARISON OF THE LOWER EXTREMITES IN SPORT-SPECIFIC AND LABORATORY ENVIRONMENTS FROM LACROSSE ATHLETES

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Introduction: T he neuromuscular coordination of the bi-articular lower extremity muscles is complex [1] and accurately collecting the synchronous motion of the joints can be challenging. While lower extremity kinematics have been accurately collected in the laboratory setting, the ecological validity of the data may be reduced as it does not reflect an environment that is experienced during sport. Therefore, the purpose of this study is to compare lower extremity kinematics in lacrosse athletes between their field environment and within the lab.

Methods: 5 Varsity lacrosse athletes (M: 2, F: 3; Age: 21.6 [4.3) performed a three-cone drill on the field and a 90˚ cutting manoeuvre in the laboratory. Motion capture data was collected using a markerless motion capture system (Theia Markerless, Kingston, ON) where the tasks were recorded using eight cameras sampling at 120 Hz (Sony, Tokyo, Japan). Kinematic data was processed using Visual 3D (C-Motion Inc., Boyds, MD) the range of motion (RoM) was calculated as the difference between the minimum and maximum angles for the cutting phase of each task. A one-way rmANOVA was used (IBM SPSS, V28; Armonk, NY, USA) to quantify differences between tasks.

Results: Right and left knee ROMs were significantly greater, for all motions, for the three-cone drill task compared to both cutting tasks ($p < 0.05$) (Table 1).

Discussion and Conclusions: The increased knee ROM in the lacrosse athletes on the field suggests that they may be at an increased level of performance when compared to the laboratory environment. They are expanding the use of the lower extremity kinetic chain that involves the knee to achieve task completion in an environment they are familiar with. Having the athletes on the field rather than in a laboratory environment to perform similar tasks may help sustain improved knee joint performance. This further suggests that researchers and clinicians need to consider the environment and the type of task used for assessment when quantifying an athlete's risk of injury or readiness to return-to-sport.

Table 1: Right and left knee ROM for knee flexion/extension, abduction/adduction and internal/external rotation were all greater in the sport specific environment than in the laboratory (*p<0.05 compared to cutting tasks)

Right Knee	**Flexion/ Extension (˚)**	**Abduction/ Adduction (˚)**	**Internal/ External Rotation (˚)**	***Left Knee***	**Flexion/ Extension (˚)**	**Abduction/ Adduction (˚)**	**Internal/ External Rotation (˚)**
Cut Left	83.98 [7.46]	27.96 [4.20]	38.32 [8.90]	**Cut Left**	93.29 [6.87]	34.24 [5.52]	39.13 [10.73]
Cut Right	96.59 [8.10]	36.40 [5.02]	40.49 [5.47]	**Cut Right**	83.72 [7.21]	30.78 [5.96]	36.01 [3.77]
Three Cone Drill	109.81 [9.38]*	57.01 [2.69]*	59.83 [0.96]*	**Three Cone Drill**	116.24 [10.00]*	58.28 [1.10]*	60.58 [0.27]*

THE INFLUENCE OF DECORIN, A PRO-INFLAMMATORY STIMULANT, ON THE MECHANICAL PROPERTIES OF THE ANNULUS FIBROSUS

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Introduction: Previous literature has investigated the biomechanical properties of various animal models, but few have studied an isolated and intact rat tail annulus fibrosus. Decorin, a class 1 small leucine-rich protein (SLRP), has the potential to trigger an inflammatory environment as previous research has shown that it can stimulate inflammation via the toll-like receptor (TLR) pathway [1]. An increased inflammatory environment can have biomechanical implications for the disc, and so the purpose of this study was to investigate the potential of decorin, a proteoglycan native to the intervertebral disc, to stimulate a pro-inflammatory environment and alter the mechanical integrity and tensile properties of a rat tail annulus fibrosus.

Methods: Sixty whole annulus fibrosus samples were dissected from 15 rat tails. The samples were randomized into three culture conditions: i) control (n=20); ii) low dose – 0.5µg/mL decorin (n=20); iii) high dose – 5µg/mL decorin (n=20). All samples were cultured in an incubator for 6 days and then mechanically tested via a tensile mechanical testing system (BioTester, Cellscale, Waterloo, ON.). Various tensile mechanical properties were analyzed including Young's Modulus, stress (MPa) and strain (%) at the end of the toe region, at initial failure, and at ultimate tensile strength.

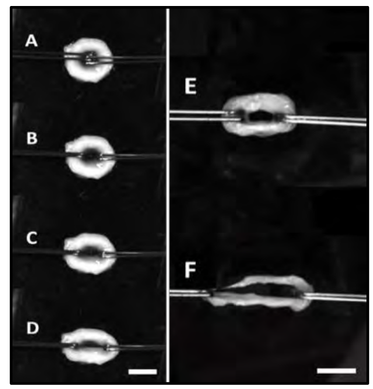

Figure 1. Various stages of AF ring failure test. A) Unloaded. B and C) Mounted ring with increasing rake-to-rake displacement. D) Preloaded (50mN). E and F) Second sample preloaded (E) and after failure (F). Scale bar = 2 mm in both panels.

Results: No significant findings for disc mechanics were observed in this study. Although a visible and reoccurring trend of increasing strength was seen in response to increasing decorin concentration, contrary to what was hypothesized. ELISA (enzyme-linked immunosorbent assay) kits were used to determine the concentration of two proinflammatory cytokines (IL-6 and MIP-2) in culture media collected at day 6. No significant findings for cytokine concentration were observed in this study.

Discussion and Conclusions: Decorin did not significantly alter disc mechanics in an isolated and free-floating rat tail annulus fibrosus. Interestingly, despite previous research documenting inflammation following exposure to decorin [1], this was not found to be the case in the current work. It is possible that annular cell death occurred, either due to the long incubation period, or high concentrations of decorin utilized, resulting in fewer cells to mount an inflammatory response. Future work is necessary to investigate the relationship between decorin concentration and mechanical properties, however, a shorter incubation period, along with testing the media at various time points, is suggested.

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HAND TRANSMITTED VIBRATION DURING IMPACT WRENCH USE

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Introduction: Prolonged use of hand-held vibratory power tools is a risk factor for vascular, neural, and musculoskeletal disorders [1], collectively known as hand-arm vibration syndrome. Hand transmitted vibration (HTV) is dependent on several factors, including the magnitude and frequency content generated by the vibratory power tool [2]. However, there is a need to better understand the effects of physical risk factors on HTV, including the combined effects of hand-arm postures and repetitive efforts that may cause neuromuscular fatigue over time.

Methods: Eight healthy males performed 4 sets of repetitively tightening 20 nuts onto bolts using a pneumatic impact wrench (NO-058-9327-4, Mastercraft, Toronto, ON) with their dominant hand. The task was performed in two postures (arm by side versus arm above shoulder) on separate testing days. Triaxial accelerometry (S3-1000G-HA, NexGen Ergonomics, Pointe-Claire, QC) measured vibration at the tool's handle and the participant's hand (3rd metacarpal) at 2500 Hz. Vibration transmissibility from the tool to the hand was calculated as a function of their respective power spectral densities in MATLAB (The MathWorks Inc., Natick, MA). Maximum grip force (ADInstruments, Colorado Springs, CO) was measured before and after each set to assess fatigue development. Surface EMG further quantified fatigue of the biceps brachii, triceps brachii, flexor carpi radialis, flexor carpi ulnaris, flexor digitorum superficialis, extensor carpi radialis, extensor carpi ulnaris, and extensor digitorum. Both grip force and electromyography were collected in LabVIEW (National Instruments, Austin, TX) at 4000 Hz. Changes in median power frequency and normalized peak muscle activity were calculated to assess neuromuscular fatigue. Repeated measures ANOVAs tested the effects of hand-arm posture and set number on vibration transmissibility, maximum grip force, and electromyography metrics (α=0.05).

Results: Preliminary analysis (n=6) showed a main effect of posture on dominant frequency of HTV in the medial-lateral (Y-) axis ($F_{1,4}$=23.86, p=.008; Figure 1). There was a higher dominant frequency with the arm by the side compared to the above shoulder posture. There was also a main effect of set number on the Y-axis dominant frequency ($F_{1,4}$=21.93, p=.009); however, post-hoc tests did not reveal a clear trend throughout sets 1−4.

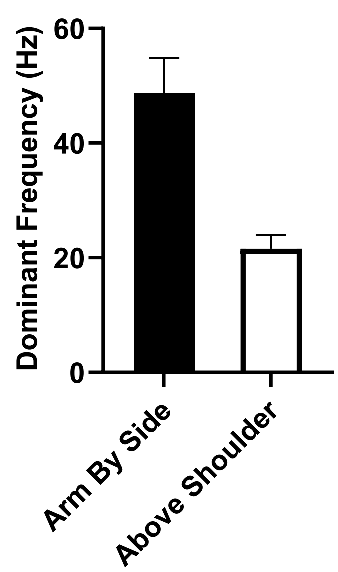

Figure 1. Mean (± SEM) Dominant frequency of hand transmitted vibration.

Discussion and Conclusions: Higher frequency content of HTV with the arm by the side likely stems from differences in magnitude and distribution of hand contact forces. These differences in HTV indicate greater injury risk to the hand and forearm when the tool is held by the side of the body; in contrast, injury risk to the upper arm and shoulder is higher in the above shoulder posture.

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EFFECT OF SUBTHRESHOLD VIBRATORY INPUT ON STANDING BALANCE IN YOUNG AND OLDER ADULTS

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Introduction: Subcutaneous mechanoreceptors in the foot sole provide tactile feedback about spatial pressure distribution to guide corrective postural responses [1]. Subthreshold mechanical noise can increase the detection threshold of these receptors to weak stimuli [2]. When subthreshold vibration is applied to the foot sole during quiet standing, some studies have reported that young and older adults exhibit decreases in sway radius, sway area [3] and root mean square of the center of pressure (COP) in both the anterior-posterior (AP) and medial-lateral (ML) directions [4]. However, the effects of vibration are not consistent, as others have found no change in standing sway in young adults [5]. Due to the heterogeneity of measures and methods of vibration used in these previous studies, it is difficult to conclude if the benefits of subthreshold vibration on balance control are limited to populations with balance deficits (e.g., older adults) or can be extended to all individuals.

Aim: The purpose of this study is to investigate the effect of subthreshold vibration on standing balance control in young and older adults.

Methods: Twenty-four young adults have been tested and twenty-four older adults (65 years or older) will be recruited for this study. Participants will complete seven 60-s standing trials, where they will stand quietly on top of custom pads placed on a force plate with their eyes closed. Each pad will contain three vibratory tactors (C-2; Engineering Acoustics, Winter Park, FL) aligned with the head of the first and fifth metatarsal, and heel. Earplugs will be worn to remove auditory cues when the tactors are active. The seven standing trials will consist of one familiarization trial, followed by three trials with vibration and three trials without vibration. The order of the vibration and no vibration trials will be pseudorandomized and counterbalanced between participants. During the vibration trials, the tactors will deliver an unfiltered subthreshold vibration at an intensity corresponding to 90% of sensory threshold for each tactor location. Sensory threshold is defined as the lowest vibratory amplitude that the participant can perceive for a given tactor site. Static balance control during the 60 s trials will be assessed using force plate AP and ML COP parameters, including the peak-to-peak amplitude, the standard deviation, and the mean velocity.

Expected Results: Initial findings indicated no changes in COP parameters between the vibration and no vibration conditions in young adults. Due to decrements in tactile sensation with aging, it is hypothesized that the application of vibration to the foot sole will decrease all COP measures, indicating a more stable balance control, in older adults. If this result is observed, this will indicate that subthreshold vibration may be propitious to those who display poor balance control.

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BEYOND SAGITTAL LUMBAR POSTURES IN SITTING AND STANDING: THE ASSOCIATION BETWEEN LATERAL ASYMMETRIES AND LOW BACK PAIN

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Introduction: Encouraging movement of the lumbar spine in sedentary activities, such as sitting and standing, appears to be beneficial for spine health [1, 2]. However, previous analyses and interventions often emphasize sagittal motion of the lumbar spine. The objective of this study was to assess frontal plane motion of the pelvis and lumbar spine during two hours of seated and standing office work and evaluate its association with transient low back pain.

Methods: Twenty-one participants (10F, 11M, age: 18-35 years) completed two hours of seated and standing office work. Pelvic obliquity and lumbar lateral bending angles (standing = 0°, right +) were calculated from the inclination of accelerometers (ADXL335, Analog Devices, MA, USA) adhered at L1 and S1. Participants rated their low back pain on a 100 mm visual analogue scale. Participants completed 15-minute blocks of typing, reading comprehension, and data entry tasks each hour. Four-way mixed ANOVAs ($\alpha = 0.05$) compared the effects of posture, computer task, time, and sex on the mean angles in each block. Two-way mixed ANOVAs compared the effect of posture and sex on angles at 10, 50, and 90% of an amplitude probability distribution function (APDF) and total range of motion. Multiple backward linear regressions were performed to test the association between peak low back pain in sitting and standing and the absolute mean and range of motion of pelvis obliquity and lumbar lateral bending angles in sitting and standing.

Results: Pelvis and lumbar postures were more symmetrical in standing than sitting. Participants exhibited greater pelvic obliquity to the left at 10% of the APDF (-3.6°), and hence, larger pelvic obliquity total range of motion (4.7°) in standing. As well, participants demonstrated less lumbar lateral bending to the right at 10, 50, and 90% of the APDF (2.2°) in standing. Generally, most participants favoured lateral motion to a single side for the duration of the exposure. Angles remained consistent over time, with small differences emerging for lateral bending angles between the 1st and 2nd hour in female participants. There were no significant correlations between low back pain and pelvic obliquity or lumbar lateral bending (Figure 1).

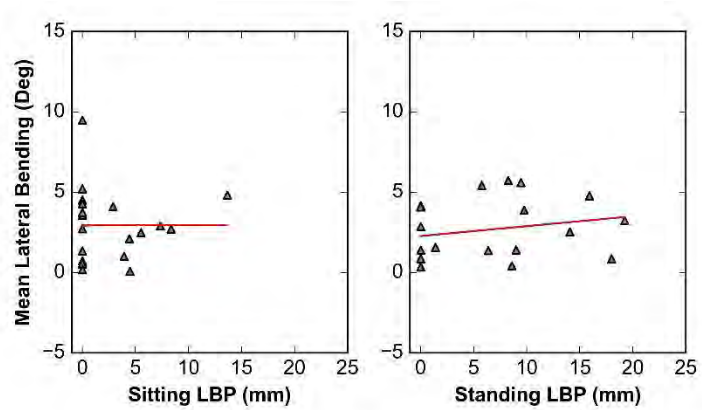

Figure 1: Correlation between low back pain (LBP) in sitting (A) and standing (B) and the mean absolute lateral bending angle.

Discussion: In both sitting and standing, participants displayed lateral asymmetries for the pelvis and lumbar spine, but associations between frontal plane motion and low back pain were not observed. Nevertheless, consideration of natural lateral spine motion in sitting and standing may be useful when developing interventions which aim to promote movement in sedentary tasks.

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COMPARISON OF YOUNG AND ELDERLY SMALL STATURE FEMALE RIB FRACTURE IN SIDE IMPACTS OF VARYING VELOCITIES

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Introduction: The aged population has a higher incidence of thorax injury than their young counterpart under similar loading [1]. Thoracic injury (e.g. flail chest, single, and multiple rib fractures) is amongst the leading causes of mortality in car-crash scenarios for the elderly population [1]. In addition, small stature females have demonstrated a higher likelihood of injury compared to an average stature male [2]. Researchers have attributed the increased incidence of injury and mortality in elderly small stature females to differences in material properties and geometry between the age and sex groups [3]. In particular, the material properties of the cortical bone in the ribs have been shown to degrade with age [4], potentially contributing to the increased incidence of injury in the elderly population [3]. Finite Element (FE) Human Body Models (HBMs) have been a useful tool to increase the understanding of the biomechanics of injury. In this study, a previously developed 84-year-old (YO) subject-specific small stature female model [5] ($F05_{86SS}$) and a 26-YO model ($F05_{26}$) were used to investigate the effect of aged geometry and material properties in side impact response.

Methods: The material properties of the cortical bone in the ribs in the $F05_{26}$ and the $F05_{86SS}$ models were modified to represent the respective age groups based on literature data [4]. The HBMs were positioned in a side impact sled and subjected to three impact severities (3.3 m/s, 4.99 m/s and 6.6 m/s). Rib fracture is represented in the models as element erosion based on a maximum plastic strain threshold. Rib fracture was monitored and compared between the models and impact velocities.

Results: At the 3.3 m/s impact velocity, both models predicted zero rib fractures. The number of rib fractures increased with increasing impact velocity for both models. The difference in rib fracture outcome between the $F05_{86SS}$ and $F05_{26}$ was the most evident at the highest (6.6 m/s) impact velocity.

Discussion and Conclusions: The aged model demonstrated a higher number of rib fractures compared to the young model, agreeing with epidemiological findings. The present study suggests that models accounting for the aged posture, rib orientation, rib shape and rib cortical bone material properties can generally replicate epidemiology. These models can inform the development of safety systems that better protect the elderly population.

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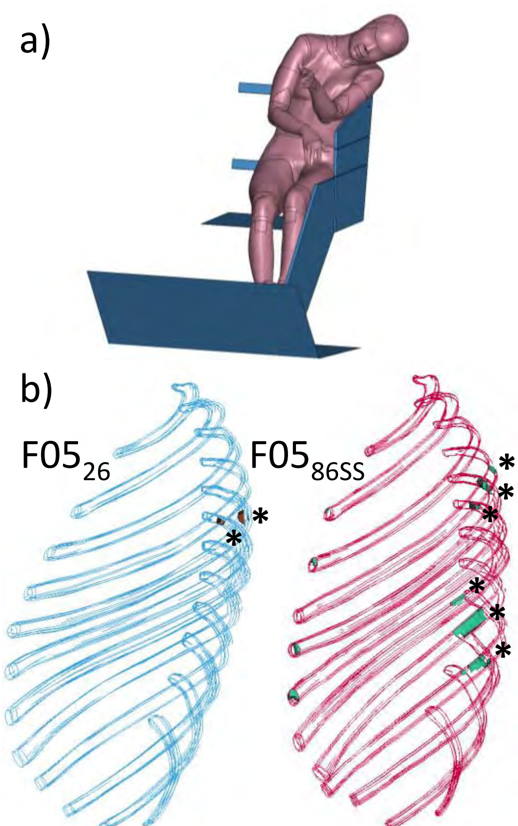

c)

Rib Fractures	3.3 m/s	4.9 m/s	6.6 m/s
$F05_{26}$	0	0	2
$F05_{86SS}$	0	3	6

Figure 1: a) HBM in a side impact sled simulation, b) rib fracture (*) in the $F05_{26}$ (blue) and $F05_{86SS}$ (red) at 6.6 m/s and c) the number of rib fractures for three impact velocities.

A DESCRIPTIVE ANALYSIS OF THE UPPER BODY KINEMATICS OF CONDUCTORS

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Introduction: A high prevalence of physical symptoms of musculoskeletal disorders (e.g., pain and numbness) has been identified in conductors, which follows trends observed in comparable and more extensively researched tasks in light manufacturing[1] and drum kit[2] or violin performance[3]. Posture and repetition are known risk factors for work-related musculoskeletal disorders[4] (WMSDs); however, conductors’ exposures to these risk factors have never been examined.

Aim: To describe the movement patterns of the upper extremities of experienced conductors while conducting their ensemble.

Methods: Participants will complete an intake form to obtain demographic information (e.g., conducting education and experience, details about ensemble, etc.). They will then be instrumented with the Xsens MVN Awinda™ motion capture system. (Movella, Enschede, Netherlands) Following the calibration process, participants will conduct their ensemble through 15-30 minutes of nearly performance-ready music during a regular rehearsal. Outcome variables include the mean, median, maximum, and minimum joint angles, the joint range of motion, and the intra-subject variability for all available rotations of the upper limb (i.e., wrist, elbow, and shoulder), trunk, and neck joints (e.g., flexion, extension, internal/external rotation, etc). Percent time spent in neutral and non-neutral postures will also be analyzed. Outcome variables will be calculated for each individual musical piece and for the total time spent conducting. The right and left sides of the body will be examined separately for the wrist, elbow, and shoulder joints.

Expected Results: Data collection is ongoing, and the results will be reported and discussed at the conference. The results of this study will provide a foundation of knowledge in an area with otherwise limited research. They will highlight the importance for future research on injury prevention in conductors and provide a starting point upon which quantitatively supported recommendations can be made to reduce conductors’ risk of developing WMSDs. This study will serve as a proof-of-concept for future research and will aid in developing processes and procedures suitable to using motion capture data to answer research questions from social science and musical analysis perspectives, such as to better understand how the movement qualities of conducting gestures elicit different reactions from musical ensembles.

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LOW BACK RESPONSES TO DIFFERENCES IN RUNNING SHOE MIDSOLE CUSHIONING IN RECREATIONAL RUNNERS

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Introduction: Manipulating running shoe midsole cushioning has been proposed to assist with the dissipation of impact shock experienced by the lower extremities during running [1]. However, such effects have not been well studied in conjunction with the low back, which may play an important role in attenuating shock transmissions to the head [2]. Therefore, the objective of this work is to investigate how the lower limbs and low back posture may respond to footwear of different cushioning stiffness.

Methods: Thirteen recreational runners (9M, 4F) ran at 3.5 m/s on a treadmill in three shoes that ranged in midsole stiffness (Nike, Inc., OR, USA) that was quantified using a servo-hydraulic materials testing system (Instron, Norwood, MA, USA). Sagittal lumbar spine and right leg angles were collected via motion capture (Northern Digital Inc., ON, Canada), and peak shock magnitudes were determined from accelerometers (Analog Devices, MA, USA) placed at the distal tibia, L5, L1, and head. Shock attenuation was calculated as the ratio between the signal power of the inferior to superior sensors. One-way repeated measures ANOVAs were conducted to compare the effect of SHOE (PGS/RCT/ZMX) on all dependent variables. Pairwise comparisons with Bonferroni corrections were applied to all significant results ($\alpha = 0.05$).

Results: Kinematic parameters are presented in Table 1. Sagittal ankle, knee, hip, and lumbar postures were similar between footwear conditions during initial contact, but greater overall ankle and lumbar sagittal ranges of motion were observed when running in the PGS compared to the RCT or ZMX shoes. Lower shock attenuation was exhibited in the ZMX shoes, but neither peak shock magnitudes nor shock attenuation differed significantly across shoes.

Discussion: When running in softer and more compliant midsoles, participants appeared to adopt reduced sagittal ranges of motion. These postures may be reflective of the decreased overall shock attenuation capacity with softer shoes. Further investigation is suggested to understand the exact musculoskeletal mechanisms for shock attenuation in the lower back, and the potential consequences of increased midsole cushioning as an intervention for shock experienced by the spine and lower limbs during running.

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Table 1: Kinematic variables during stance phase compared across different running shoes, presented in Mean ± SD. +ve: ankle dorsiflexion, lumbar flexion. *IC*: initial contact. *ROM*: range of motion

	PGS	RCT	ZMX	*p*-value
Ankle flexion at IC (deg)	1.94 ± 5.22	0.57 ± 6.54	2.99 ± 5.20	0.256
Ankle ROM (deg)	36.80 ± 4.23	35.28 ± 4.38	35.87 ± 4.24	0.01*
Lumbar flexion at IC (deg)	-4.02 ± 6.25	-5.94 ± 7.06	-6.75 ± 8.21	0.372
Lumbar ROM (deg)	9.34 ± 4.05	7.63 ± 2.13	8.70 ± 3.41	0.03*

AGE-RELATED DIFFERENCES IN GLENOHUMERAL AND SCAPULOTHORACIC KINEMATICS USING 4DCT

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Introduction: Four-dimensional computed tomography (4DCT) is an imaging modality that provides dynamic 3D images of the shoulder complex over time. Additionally, 4DCT is non-invasive and does not suffer from soft-tissue artifact. This allows for accurate measurements of complex nonplanar motions. The objective of this study is to examine scapulothoracic and glenohumeral kinematics during the motion of internal rotation to the back. This motion is the focus because it is important for activities of daily living, but existing literature primarily focuses on planar motion, typically elevation or abduction. Additionally, this study will determine the effects of aging on scapular/humeral kinematics and range of motion (ROM) by comparing two cohorts. It is known that shoulder function is affected by age; generally, there is a decline in ROM with age, with the exception of internal rotation which increases with age [1]. Additionally, there are statistically significant differences in scapula and humerus static positioning with age [2]. Given the nature of the internal rotation to the back motion, which is not pure internal rotation, it's unclear how the motion will differ with age, although it is hypothesized that overall, the ROM will decrease with age.

Methods: Thirty healthy males were recruited and split into two groups of fifteen. One group aged 18 to 40 and one group aged 45 and over. Kinematics were measured using the Single Vertebra Image Based (SVIB) method, which is a previously established technique that employs 4DCT to image dynamic motions. Briefly, bone models are made from dynamic 4DCT scans and registered to static models to calculate six degree-of-freedom kinematics. Humerus kinematics are in reference to the scapula, and scapula kinematics are in reference to the T1 vertebra.

Results: The older cohort had, on average, more scapula movement (translations and rotations) than the younger cohort. The younger cohort however exhibited more glenohumeral translation, particularly in the anterior-posterior and superior-inferior directions. Scapulohumeral rhythm (ratio of humerus to scapula motion) was 1.97 for the young cohort and 1.77 for the older.

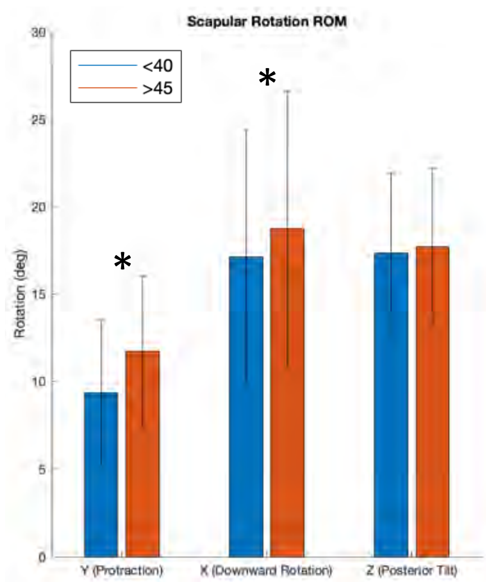

Figure 1: Scapula rotation ROM, * indicates statistical significance

Discussion and Conclusions: The results suggest that the two cohorts have different movement patterns that allow the same final position to be reached. Specifically, the older cohort utilizes the scapula more, possibly as compensation for reduced glenohumeral translation. Next steps are identifying any patterns in the correlations between the various degrees of freedom in the joints.

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THE ROLE OF DIURNAL VARIATION IN STANDING LOW BACK DISCOMFORT

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Introduction: Low back discomfort (LBD) due to prolonged standing is a phenomenon that can manifest for a multitude of reasons [1]. When examining the root causes of LBD, two distinct groups emerge: pain developers (PD) and non-pain developers (NPD) [2]. PD tend to have elevated co-activation of the gluteus medii (GM) bilaterally, and trunk flexor/extensor (i.e., lumbar erector spinae and rectus abdominis) muscles, as well as exhibit a greater number of large body weight transfers during a prolonged standing protocol [1]. Diurnal variation can be implicated in the development of standing LBD as various biomechanical changes occur to the body throughout the day [3]. These changes include a decrease in intervertebral disc height over the course of the day, which increases disc pressure and stiffness [3]. Furthermore, pain perception can fluctuate throughout the day and pain sensitivity has been found to be greatest in the evening [4]. Although, previous literature regarding prolonged standing induced-LBD have not assessed or controlled for time of day.

Aim: The **purpose** of this project is to assess the influence of diurnal variation on the development of standing-induced LBD. It is **hypothesized** that a greater proportion of the study sample will develop LBD during the evening, which will be characterized by an increase in GM co-activation, and body sway parameters.

Figure 1: Sensor setup for collecting kinematic data.

Methods: 20 healthy young participants (10 male, mean age 23 ± 4.4 years; height 172.3 ± 9.9 cm; mass 74.8 ± 15.1 kg) were recruited. Participants completed two two-hour standing protocols; one in the morning (8 AM) and one in the evening (8 PM). Surface electromyography (EMG) was used to monitor activity of three muscle groups, bilaterally: GM, rectus abdominis, and lumbar erector spinae. Full body kinematics were collected to monitor relevant postural changes, and ground reaction forces were analyzed to measure center of pressure changes. During this protocol participants completed four tasks for 30 minutes each. A visual analogue scale (VAS) was completed by participants every 15 minutes to discern subjective perceptions of pain, followed by a three-minute quiet standing period for data acquisition.

Expected Results: It is expected that there will be increased pain in the evening sessions as indicated by elevated VAS scores, higher anterior-posterior center of pressure sway and a greater degree of EMG co-activation of the GM and trunk flexor/extensors [1,2]. Furthermore, it is expected that there will be a greater number of PD in the evening sessions compared to the morning sessions [1,2].

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EFFECTS OF CYCLIC LOADING ON THE MECHANICAL PROPERTIES OF THE ANNULUS FIBROSUS

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Introduction: The intervertebral disc (IVD) is critical in the human body's ability to bear and transmit loads during a variety of activities. This study sought to evaluate the effects of prolonged cyclic loading, such as during walking and running, on the tissue-level mechanical properties of the annulus fibrosus (AF).

Methods: Porcine cervical spines were used to obtain functional spinal units (FSUs) at the C3-C4 and C5-C6 levels. Using the MTS Criterion Model 43 (MTS, Eden Prairie, MN, USA), all FSUs were pre-conditioned at 300N of axial compression for 15 minutes. The cyclic loading group then cycled between 0.35MPa and 0.95MPa for two hours (n=8). The two other conditions involved were a static loading group, undergoing 0.65MPa for two hours (n=10), and a control that only underwent pre-conditioning (n=11). Following loading, samples of the AF were excised to perform single-layer tensile testing with the Biotester (CellScale, ON, Canada), and multi-layer 180º peel test (Figure 1) with the UStretch system (CellScale, ON, Canada). Force and displacement data for tensile and peel tests were collected at 100Hz. Variables evaluated from the peel tests were strength, strength variability, and stiffness. Variables analyzed from were maximum stress, strain, and Young's modulus.

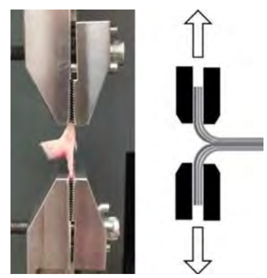

Figure 1: Multilayer specimen mounted between two actuators for 180º peel test.

Figure 2: Single layer specimen mounted for tensile testing.

Results: The analysis showed that interlamellar adhesion strength variability was higher in the cyclic loading condition than the control ($P < 0.04561$) and static (trend; $P = 0.06$) conditions. No other remarkable differences were observed between the cyclic loading protocol and the other two conditions. However, an incidental finding was that strain experienced at initial failure during the single-layer tensile tests were significantly higher in the static condition than control ($P < 0.02$).

Discussion and Conclusions: The primary finding of reduced consistency in the adhesion strength between layers of the AF provides evidence that cyclic loading could exacerbate imperfections found in the interlamellar matrices of the AF [1]. Such variability in interlamellar strength could predispose the IVD to further damage since it does not have a consistent ability to bear load. In addition, the finding that statically loaded tissues exhibited initial failure at a higher strain value indicates that those tissues experienced a longer linear region, bearing load for a longer period before the initiation of damage. These findings provide further insight into the mechanical complications of physical activity and sedentary behaviour on the spine and provoke further research into how the body's biological processes circumvent them.

AUTOMATED GOLF PERFORMANCE ASSESSMENT USING MARKERLESS MOTION CAPTURE DERIVED FROM A CELL PHONE CAMERA

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Introduction: The spine is an anatomically complex series of joints requiring refined motor control strategies to coordinate movement. Back injuries occur, in part, due to poor spine control during sudden and unexpected spine loading. Specifically, 33% of US golfers are over 50 years old, and 25-62% of complaints from golfers with musculoskeletal pain are related to the back [1]. Further, golfers perform a highly individualistic, repetitive, and dexterous task which is an excellent surrogate to investigate the relationship between spine movement mechanics, athletic performance, and related injuries. What is presently unknown is the relationship between spine movement kinematics and golf swing performance during a variety of different shot types. Further, it is unknown if pose data derived from a single video camera have any utility in the assessment of motor performance during a golf swing.

Aim: The aim of this study is threefold. The first purpose will be to compare the results of open access pose estimation algorithms against kinematics derived from a wearable IMU suit. The second purpose will be to use compare the utility of video and IMU-derived data in shot type prediction. The third purpose will be to assess the utility of video and IMU-derived data in the objective prediction of skill level (i.e., handicap).

Methods: 100 elite and sub-elite golfers will be sampled. Seven shots will be recorded for all woods and irons in a golfer's bag. During each experiment the following data will be recorded: (1) Golfer anthropometrics and demographic information, (2) club and ball kinematics (E6 Golf Simulator), (3) Full body 3D kinematics (XSens, Awinda), and (4) time-synced video (Logitech StreamCam). To address each purpose custom data routines will be developed in MATLAB with different data streams serving different objectives. For the first sub-objective IMU and video-based body kinematics will be compared. For the second objective, video- and IMU-based body kinematics will be used as inputs to inform the prediction of shot-type (i.e., club and ball trajectory data). For the third sub-objective, video- and IMU-based body kinematics will be used as inputs to inform the prediction of golfer demographics (i.e., handicap).

Expected Results: The rich dataset acquired here will aid in the objective assessment of a golf-swing using portable video- and IMU-based human body kinematics. We expect that video- and IMU-based kinematics will perform similarly in the objective assessment of different gold shot types and performance levels. Specifically, based on the kinematic modes of variation demonstrated from swing to swing, we expect to predict the golfers' a) skill level, b) shot type, and c) shot shape with a minimum prediction accuracy of >90%**.**

References:

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PREDICTIVE DYNAMIC SIMULATION APPROACH FOR ACETABULAR CUP ORIENTATION OPTIMIZATION FOLLOWING THA

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Introduction: This study aims to investigate the impact of various subject-specific factors on the optimal positioning of the acetabular cup post-Total Hip Arthroplasty (THA). The study employs optimal control-based predictive dynamic simulations of sit-to-stand (s2s) movements across three different conditions: (1) varying chair heights, (2) spinal fusion, and (3) hip and knee pain. For each condition, the predicted s2s motion is used to determine the optimal alignment of the acetabular cup, which is a crucial factor in the success of THA surgery [1], by minimizing impingement and edge-loading - the two primary causes of hip dislocation following THA.

Methods: Within an optimal control framework, a musculoskeletal model was employed to include the ankle, knee, hip, lumbar, shoulder, and elbow joints, along with 21 muscle units surrounding the hip joint. The dynamic model was used to predict the s2s motion by minimizing effort, hip/knee contact force, and joint velocities.

Results: Figure 1 displays the angular distance from impingement (AID) and edge-loading (AED) for various conditions, as defined in [2]. It is evident that conditions such as spinal fusion, knee pain, and low seat height can increase the risk of dislocation for patients following THA.

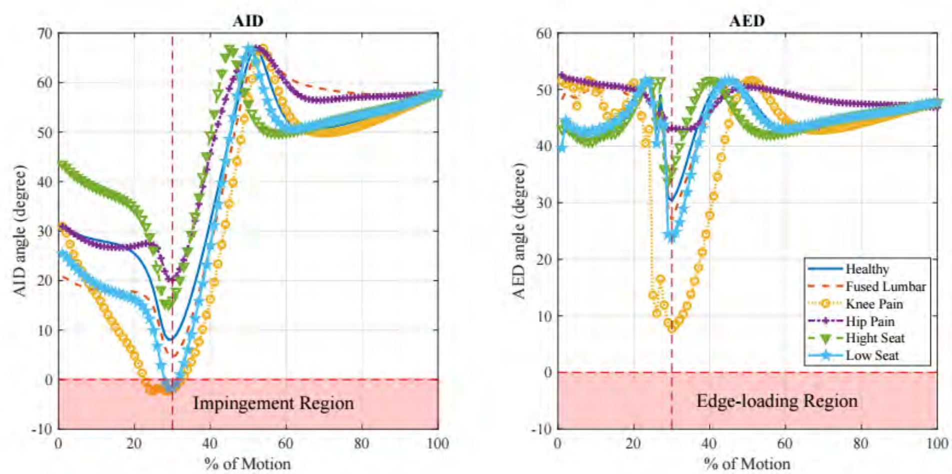

Figure 1: The AID and AED angles for predicted sit-to-stand movements with different conditions.

Discussion and Conclusions: The use of predictive dynamic simulation enabled the investigation of hypothetical scenarios to examine the influence of different conditions, including lumbar fusion and joint pain, on human movement and the subsequent optimal positioning of the acetabular cup. One noteworthy finding was that alterations in sit-to-stand movement patterns due to knee pain can be more significant than the high-risk situation of spinal fusion.

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EFFECTS OF THERABAND RESISTANCE ON SAGITTAL PLANE KINEMATICS OF THE BACK SQUAT

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Introduction: Looped resistance bands are often placed around the knees to provide proprioceptive feedback to reduce knee valgus during a squat. Research examining the effects of band use has thus far been limited to frontal plane knee mechanics. The purpose of this study was two-fold: 1) to determine if looped resistance bands altered sagittal plane kinematics of the back squat, and 2) to determine if potential changes in squat kinematics were different between male and female participants.

Methods: Subjects (10 males and 10 females) completed 3 repetitions of 4 squat conditions in random order, at 85% of their estimated one repetition maximum. Conditions included a control (no resistance band), red (medium), black (special heavy), and gold (elite) TheraBand CLX™. Three-dimensional motion capture was assessed using a 10-camera Vicon motion capture system (Vicon, Oxford, UK), which sampled the back squat at 240 Hz. Joint angles and barbell displacements were obtained using Visual3D (C-Motion, Germantown, MD, USA). These data were low-passed at 6 Hz using a fourth-order Butterworth digital filter. Following time-normalization, the descent and ascent phases were identified to describe knee, hip, and barbell kinematics, as well as coordination and variability through phase plane analyses.

Results: In the high-tension (gold) resistance band condition, knee flexion was reduced by 3.14 degrees ($p<0.001$ $\eta_p^2 = 0.209$), while descent and ascent knee joint velocity decreased ($p=0.028$, $\eta_p^2 = 0.086$), ($p=0.009$, $\eta_p^2 = 0.121$). In female subjects, a 30% increase ($p=0.04$ $\eta_p^2 = 0.076$) in knee joint variability was also observed during the ascent of the squat. Increased variability at the hip joint was observed, and in turn, coordination between the knee and hip joint were altered when bands were used. As a result of changes at the knee and hip joint, vertical barbell range of motion was reduced ($p=0.038$ $\eta_p^2 = 0.014$). The effects of the band appeared to be more pronounced with increasing band tension. Analysis of sex differences revealed coordinative differences between the male and female groups in control and band conditions, with female subjects displaying more significant changes in technique with increasing band tension.

Discussion and Conclusion: This study suggests that the effects of a looped resistance band are not limited to the fontal plane as originally intended and have several effects on sagittal plane squat kinematics. These changes are most notable in female subjects, and with heavier resistance bands. Caution should be taken when using a resistance band to correct knee valgus in loaded back squats, as band use may result in unintended changes to the overall squat pattern.

Acknowledgements: This research was support by NSERC funding to D.A Gabriel and M. Holmes.

PIC-TURE THIS: EXPLORING LOCATION-DEPENDENT MODULATION OF PERSISTENT INWARD CURRENT IN LOWER-LIMB MOTOR NEURONS BY CUTANEOUS STIMULATION

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Introduction: Persistent inward currents (PICs) are an intrinsic property of motor neurons that contribute to increasing motor neuron output for a given input. In the lower-limb, PICs are important to achieve appropriate muscle activation required for various tasks, including postural control [1]. Spindle afferents from the plantar-flexors and cutaneous afferents in the sural nerve modulate PICs in lower-limb muscles [1,2]. Foot sole skin has a role in modulating muscle activity in standing and locomotion, with evidence of a location-dependent effect [3,4]. However, it remains unclear whether cutaneous afferents from the foot sole modulate PICs in a location dependent manner.

Aim: To explore the location dependent modulation of PICs in lower-limb motor neurons by cutaneous stimulation of the heel and metatarsal foot sole regions.

Methods: Seated participants will perform isometric ramp up and down plantarflexion and dorsiflexion contractions to ~15% of their maximal voluntary contraction. Motor unit action potentials will be recorded through fine-wire electrodes inserted into the soleus (Sol), and tibialis anterior (TA) muscles. Contractions will be performed with no cutaneous stimulation (control), electrical cutaneous stimulation applied to the heel region (HEEL STIM), or the metatarsal region (MET STIM). PICs will be estimated using the paired motor-unit technique and compared between control, HEEL STIM, and MET STIM conditions for each muscle.

Expected Results: Given the strong coupling between cutaneous afferents innervating the foot sole and lower limb motor units [4], plantar cutaneous stimulation is expected to modulate estimates of PICs. Previous work has shown that HEEL STIM excites Sol and inhibits TA while MET STIM has the opposite effect. As such, in Sol we expect larger PIC estimates in the HEEL STIM condition and lower PIC estimates in the MET STIM condition compared to control. Conversely, we expect estimates of PIC in TA to be lower during HEEL STIM, but larger during MET STIM. These findings may provide insights into the potential role of cutaneous inputs in modulating motor neuron excitability of lower-limb muscles during postural tasks.

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ASSESSING THE RELIABILITY OF MAXIMUM VOLUNTARY CONTRACTION PROTOCOLS

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Introduction: Baseline maximum voluntary contractions (MVCs) are commonly used in occupational biomechanics research to establish a reference value for subsequent contractions. MVCs allow researchers to normalize workloads as a percentage of maximum force/torque, across both individuals and experimental sessions, and serve as an important evaluation metric in ergonomics assessments [1]. Despite the importance of accurate baseline MVCs, numerous MVC protocols are reported in the literature, with no clear consensus on a reliable standardized procedure.

Aim: The primary aim of this study is to determine the most reliable method of obtaining baseline MVC values between experimental sessions. A secondary aim is to determine the effects of familiarization sessions on the between-session reliability of baseline MVCs.

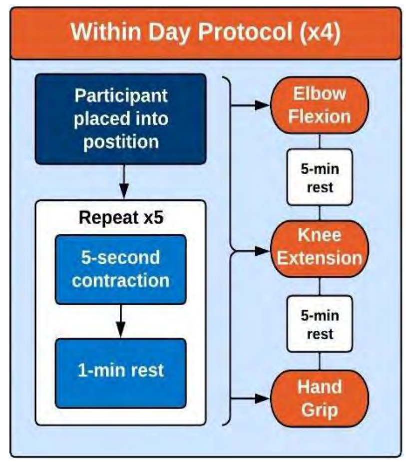

Figure 1: Experimental Protocols

Methods: 30 participants (15F, 15M) aged 18-35, with no acute or chronic upper or lower limb pain, injury, or surgery in the previous 12 months, will be recruited from the university's student population. Participants will perform 3 sets of 5 MVCs, each lasting 5 seconds, with 1 minute of rest between contractions, and 5 minutes of rest between sets (Figure 1). Knee extension and elbow flexion MVCs will be conducted on the HUMAC NORM isokinetic dynamometer (Computer Sports Medicine Inc., Stoughton, MA, USA), and hand grip will be measured using a JAMAR Hydraulic Hand Dynamometer (Patterson Medical Inc., Warrenville, IL, USA). These protocols will repeat 4 times in total, 24–48 hours apart. At each visit to the lab, participants will perform these MVC blocks in a randomized order to control for task order effects. We will examine 18 methods of calculating baseline MVC: Peak of 1-5 exertions, and the average of 2-5 exertions, all with and without a familiarization session. For each MVC calculation, relative reliability will be determined using intra-class correlation coefficients (ICCs), while absolute session reliability will be established using standard error or measure (SEM).

Expected Results: We anticipate differences in between-session reliability between each method of calculating a participant's baseline MVC. We hypothesize that the mean of 3 measures will yield the highest between-session reliability (ICC & SEM), while minimizing strength reduction due to fatigue. The results from this study can help inform future biomechanics research that heavily rely on accurate baseline MVCs as part of the experimental manipulations being undertaken.

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KNEE AND L5/S1 PEAK FLEXION MOMENTS DURING SQUAT, STOOP, AND STRADDLE LIFTING TECHNIQUES

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Introduction: In childcare, educators are required to lift infants from the floor. Floor-level lifting has been shown to result in musculoskeletal injuries [1]. Squat, stoop, and straddle lifting are techniques that have been compared in literature with varying degrees of knee and back flexion required. Knee flexion moments were significantly reduced using a single limb rising technique compared to a double limb rising technique [2]. Another asymmetrical technique, the straddle lift, decreased participants rating of perceived exertion and erector spinae activity compared to an untrained lift [3]. The objective of this study was to compare knee and L5/S1 peak flexion moments during the three lifts. It was hypothesized that the straddle lift would produce the greatest knee and smallest L5/S1 peak knee flexion moments.

Methods: Thirteen healthy participants completed three squat, stoop, and straddle lifts with an 11 kg sandbag representing a 90th percentile infant. Kinematic data was collected using an Optotrak Certus® system (NDI, ON, Canada). Kinetic data was collected using four AMTI force platforms (AMTI, MA, USA). Bilateral knee and L5/S1 flexion moments were calculated for each lifting technique using Visual 3D (C-Motion Inc., MD, USA), and normalized to %BW × Ht. A two-way (lift technique × joint) repeated measures ANOVA was performed on peak flexion moments.

Results: A significant main effect of lift technique ($p < 0.01$) and joint ($p < 0.01$) exists. A significant lift technique × joint interaction ($p < 0.01$) exists. Preliminary correlation between L5/S1 and left ($p = 0.984$) or right ($p = 0.173$) peak knee flexion moment does not exist.

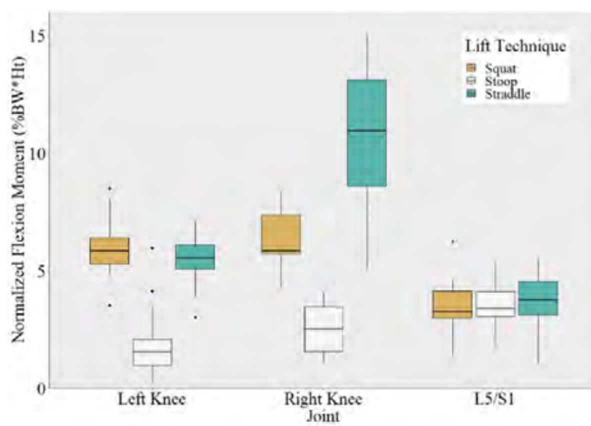

Figure 1: Normalized flexion moment for each lift at each joint.

Discussion and Conclusions: Peak knee flexion moments are smallest in the stoop. Some participants' bent knees during this lift could have attenuated L5/S1 peak flexion moments, compared to a straight-legged stoop lift. The straddle involves a heels-up squat foot position for the right leg, loading the right knee further while the left knee is not loaded any less in a flat-foot squat foot position as seen in this study and literature [4]. Despite previous work [3] indicating reduced muscle activity, the straddle lift yielded similar L5/S1 peak flexion moments to the squat and stoop. Thus, although literature favours asymmetrical techniques, our results suggest straddle lifting a child off the floor lacks a sagittal plane advantage and may overload other joints. Further research could consider studying balance outcome measures for these lifts.

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CONCOMITANT ACL-MENISCAL TEARS DO NOT ALTER ENERGY ABSORPTION DURING LANDING COMPARED TO ISOLATED ACL TEARS IN PEDIATRIC PATIENTS

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Introduction: In the past two decades, there has been a 2.3% yearly increase in anterior cruciate ligament injuries (ACL) [1]. Additionally, concomitant ACL and meniscal tears have a 79% incidence rate [2]. While it is known that the menisci are important for sustaining recurrent impact loads and can affect knee energy absorption, there is a lack of research examining the effects of how concomitant ACL and meniscal tears can impact dynamic movement of the lower limbs within the pediatric population [3].

Aim: To investigate whether there is a difference between concomitant ACL + meniscal tears and isolated ACL tears for energy absorption during a drop vertical jump in pediatric patients.

Methods: This cross-sectional study included 53 participants with an MRI confirmed ACL rupture. Patients were grouped based on isolated ACL injury (ACLi, n=13, 10 females, 15.5 ± 1.0 years old, 1.63 ± 0.08 m, 62.4 ± 11.9 kg) or concomitant ACL and meniscal tear (ACL+ men, n=40, 29 females, 15.3 ± 1.4 years old, 1.68 ± 0.08 m, 64.8 ± 12.6 kg). Participants performed a series of bilateral drop vertical jumps preoperatively. The eccentric (landing) portion of five successful trials were considered for analysis. The trajectories and ground reaction forces (GRF) of the injured limb were filtered using a 4th order zero-lag low-pass Butterworth filter with a cut-off frequency of 15 Hz. Energy absorption was estimated as the integral of joint power by multiplying the moment by the angular velocity for each joint (ankle, knee and hip). We used one-way ANOVA to compare groups.

Results: Energy absorption was not different between ACL + men and ACLi groups for the hip, knee and ankle (Table 1).

Conclusion: Pediatric patients with concomitant ACL and meniscal tears do not differ from isolated ACL tear for energy absorption during drop vertical jumps.

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Population	Ankle (%)	Knee (%)	Hip (%)	Ankle (p)	Knee (p)	Hip (p)
ACL + men	11.06 ± 10.94	27.26 ± 6.13	61.69 ± 12.20	0.154	0.682	0.146
ACLi	6.39 ± 5.98	26.40 ± 5.98	67.21 ± 9.09			

Table 1. Energy absorption of the ankle, knee and hip comparison between patients with an isolated anterior cruciate ligament (ACLi) vs. concomitant ACL-meniscal tears (ACL + men). Data presented as mean (standard deviation). P values determined via ANOVA.

ISOMETRIC AND ISOKINETIC TORQUE IN ACL DEFFICIENT ADOLESCENTS WITH AND WITHOUT MENISCAL TEARS

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Introduction: The anterior cruciate ligament (ACL) is the most commonly injured ligament in the knee. It is uncommon for an ACL tear to be isolated, and concomitant ACL and meniscal tears have a 52-63% incidence rate [1]. Following ACL rupture, muscle strength deficit and altered neuromuscular control can occur [2]. It remains unclear how these variables differ preoperatively by the presence of a concomitant meniscal tear amongst pediatric athletes.

Aim: The purpose of this study was to examine the differences in torque and muscle activation between athletes with isolated ACL rupture and concomitant ACL rupture and meniscal tear.

Methods: This cross-sectional study included forty-seven participants with an MRI confirmed ACL rupture grouped based on isolated ACL rupture (iACLr) or rupture with meniscus tear (ACLrm). Participants performed isometric and isokinetic tasks preoperatively. Maximum voluntary isometric contractions were performed on a dynamometer (System 4 Pro, Biodex Medical Systems, USA) at 60° knee flexion, and isokinetic tasks were performed for 44 repetitions at 90°/s, from 10-100°. Torque data was sampled at 2000Hz, low pass filtered at 10Hz, and normalized to body weight. The first five isokinetic repetitions were averaged. A Mann-Whitney U test was used to compare muscle activation and torque levels between groups.

Results/Expected Results: No significant isokinetic or isometric torque differences were observed in either limb among iACLr [n = 13; age = 15.5 ± 1.1yrs; weight = 62.4 ± 11.9kg] and ACLrm [n = 34; age = 15.3 ± 1.4yrs; weight = 64.8 ± 12.6kg] participants. However, injured limb ISOKIN quadriceps and ISOM hamstrings torque were trending towards significance (Table 1).

Conclusion: Preoperative functional outcomes related to muscle strength do not differ among ACL deficient adolescents with and without meniscal tears. Electromyography analysis is still in progress.

References:

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Table 1: Comparison of isokinetic torque among participants with isolated ACL tears vs concomitant ACL and meniscal tears. Data presented as median and 95% confidence interval.

	Isokinetic strength			**Isometric strength**		
Outcome	Concomitant	Isolated	p	Concomitant	Isolated	p
Quadriceps torque of injured limb	1.22 (1.14-1.45)	1.12 (0.66-1.28)	0.055	2.54 (2.28-2.67)	2.18 (1.74-2.84)	0.108
Quadriceps torque of contralateral limb	1.34 (1.22-1.58)	1.16 (1.03-1.60)	0.258	2.70 (2.55-2.95)	2.79 (2.35-3.35)	0.548
Hamstring torque of injured limb	1.09 (1.02-1.30)	0.99 (0.68-1.38)	0.214	1.08 (1.05-1.19)	0.940 (0.84-1.26)	0.069

A COMPARISON OF DRIVING VS NON-DRIVING MUSCLE FORCES ON A NOVEL MUSCLE ACTUATOR SYSTEM

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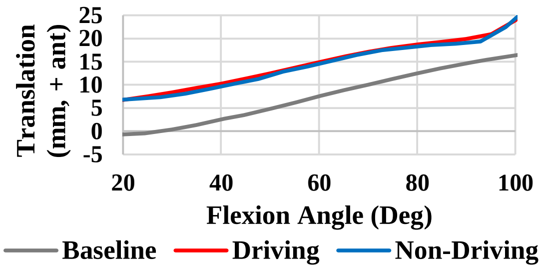
Introduction: Conventional joint motion simulators for pre-clinical testing of total knee arthroplasty (TKA) designs manipulate the knee in directed force, displacement, or simulated muscle control; however, a rig capable of using all three control modes has only recently been described [1]. The muscle actuator system (MAS) can generate gravity-dependent, quadriceps-controlled squatting motions and is mounted onto a force/displacement-control capable platform (VIVO, AMTI, Watertown, MA, USA). The purpose of this work is to compare the kinematics of muscle-driven motion with displacement-driven motion and non-driving muscle loads applied.

Methods: A phantom TKA knee was created, utilizing cruciate sacrificing components (Triathlon PS, Size 4, Left, Stryker, Mahwah, NJ, USA). The knee was mounted onto the testing platform. Three motion studies were conducted. First, the baseline motion of passive flexion/extension was performed. Next, motion was repeated; this time driven by quadriceps control. Quadriceps forces at distinct flexion angles were extracted. Finally, a third test was performed; flexion angles were prescribed, but with the previously-extracted forces applied at their respective flexion angles. An optical tracking system (Optotrak Certus, NDI, Waterloo, ON, Canada) measured tibiofemoral (TF) kinematics. Nominal TF kinematics, including anterior-posterior translations (Figure 1) were compared using root-mean square errors (RMSE).



with respect to TF flexion.

Results: During extension, the tibia translated posteriorly for all three motions. The baseline was shown to be offset posteriorly throughout. In comparison to the baseline, the muscle-driven and non-driven motions had RMSEs of 7.1 mm and 6.5 mm, respectively (Table 1). Comparing muscle-driven with non-driven motion yielded a RMSE of 1.1 mm.

Discussion and Conclusions: Kinematics do not need to be muscle-driven, but accurate quadriceps forces should be applied to provide a better representation of physiological motion.

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Table 1.	ML (mm)	AP (mm)	SI (mm)	IE (degree°)
Driving vs Baseline	0.5	7.1	0.3	2.6
Non-Driving vs Baseline	0.6	6.5	0.3	2.1
Driving vs Non-Driving	0.2	1.1	0.3	0.8

INVESTIGATING THE REPEATABILITY OF COMPENSATORY MOVEMENTS IN ROTATOR CUFF TEARS TO IMPROVE WEARABLE DEVICE TRACKING

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Introduction: Rotator cuff tears (RCT) are a common cause of shoulder pain and may hinder functional capabilities [1]. A conservative treatment approach is often recommended [2], but adherence to prescribed at-home physiotherapy exercises remains challenging to confirm due to subjective responses and recall biases [3]. Wearable devices paired with machine learning algorithms can objectively track and identify human activity [4], but their utility to evaluate RCT rehabilitative exercises is unclear. Little research has focused on exercises and compensatory movements, often observed in symptomatic RCT individuals. Producing repeatable compensatory movements according to cues can be used to highlight kinematic compensatory differences, train machine learning algorithms for wearable devices, and improve assessments of a client's adherence to exercise plans, and potentially motivate adherence.

Aim: To investigate the reliability of reproducing compensatory shoulder abduction exercise cues associated with rotator cuff injuries within repetitions and between sessions.

Methods: Sixteen healthy, asymptomatic adults (8 male, 8 female) free of shoulder pain or injury will participate in two sessions. Three-dimensional kinematics of the upper extremities and thorax will be recorded using an 11-camera Vicon MX20+ motion tracking system at a sampling rate of 50 Hz (VICON, Oxford, UK). A wrist-worn smartwatch on the active extremity will collect tri-axial acceleration and gyroscope data. At each session, asymptomatic classification for each arm will be evaluated and confirmed with negative results from two standard clinical shoulder impingement tests. Participants will receive standard and compensatory cues, generated from health professionals, for shoulder abduction rehabilitative exercise with a weight in hand (0.5 kg). Trials will be collected on both arms with standard and compensatory cue conditions for a total of four trials of twenty repetitions in one session. Thoracohumeral elevation and thoracohumeral and forearm axial rotation joint angles associated with shoulder abduction compensatory cues of the right arm and torso will be evaluated. Statistical parametric mapping and Mann-Whitney U tests will be used to evaluate differences within repetitions and between sessions.

Expected Results: We hypothesize thoracohumeral elevation and thoracohumeral and forearm axial rotation kinematics will not vary within repetitions and between sessions while performing compensatory shoulder abduction rehabilitative exercises. Repeatability of compensatory movements can be used to help confirm and validate that individuals can consistently produce movements according to cues and could produce a reliable and robust compensation data set to improve wearable device tracking, and ultimately overall adherence to exercise plans.

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AN ADAPTIVE ROBOTIC REHABILITATION TRAINING PROGRAM FOR PERSONS WITH MULTIPLE SCLEROSIS

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Introduction: Multiple Sclerosis (MS) is a chronic, inflammatory, and autoimmune disease affecting the central nervous system, causing detriments to the upper limb in 66% of diagnosed individuals [1,2]. Robotic devices have gained popularity for upper limb rehabilitation as a complement to traditional therapies because they exploit low resistive loads at high repetitions, a modality known to stimulate neuroplasticity [3]. They are a safer modality for severely weakened limbs whereby conventional resistance training may not be optimal [4]. Robotic rehabilitation is effective for individuals with stroke, but limited research exists on how it affects those with MS.

Aim: To implement an 8-week adaptive and resistive robotic training program of the upper limb to improve muscular strength and motor capabilities for individuals with multiple sclerosis.

Methods: 30 participants with varying levels of MS will complete robotic rehabilitation tasks in a longitudinal design. Participant groups will be divided based on limb completing the training (more or less affected limb). Participants will perform eccentric contractions against resistive force in combinations of flexion/extension and radial/ulnar deviation, while using an adaptive haptic robot (Wristbot, Genoa, Italy; Figure 1), 3 times weekly for 8 weeks. Based on performance, an initial resistance of 40% of the participant's maximal strength will be modified in 5% increments. Outcome measures of motor performance, neurophysiology, and muscular strength will be taken at baseline/post-intervention/1-month follow-up to evaluate upper limb muscular strength, functionality, and dexterity. Neurophysiological measurements will be examined using transcranial magnetic stimulation. Strength measures will include maximal grip and wrist strength. Motor performance will be evaluated using a battery of robotic assessments including tracking error, proprioception, and stiffness.

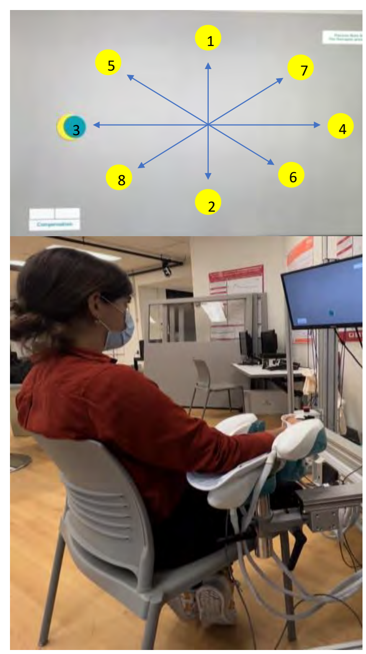

Figure 1. Robot reaching task locations (top) and participant

Expected Results: Over 8 weeks of robotic rehabilitation, participants are expected to show increased muscle strength, motor control, and corticospinal excitability. This research contributes to the robotic rehabilitation field by proposing a novel adaptive approach and suggests a challenge-based paradigm that adapts to the user's performance.

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EXPLORING THE LOCATION DEPENDENCE OF CUTANEOUS REFLEXES IN THE ABDUCTOR HALLUCIS MUSCLE

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Introduction: The glabrous skin of the foot sole contains four classes of low-threshold mechanoreceptors to relay sensory information for reflex responses that are important for postural control (1). The abductor hallucis (AH) is the largest intrinsic foot muscle which is responsible for great toe flexion, abduction, and longitudinal arch support (1). Studies have shown that the AH is the most active foot muscle for the majority of postural positions (1). In other postural muscles (e.g., lower-limb muscles), cutaneous reflexes are topographically organized in a location dependent manner to generate functional balance responses (3). Hence, with the AH's role in posture, it is possible that cutaneous reflexes in this muscle are also location dependent. This, however, remains unknown.

Aim: To characterize the AH's cutaneous reflexes across four-foot regions and identify whether it is also topographically organized in a location dependent manner. Ultimately this knowledge can then be applied to designing clinical interventions to inhibit or excite cutaneous afferents in order to generate reflex responses to aid in balance.

Methods: In a seated posture, 8 neurologically healthy individuals held 20% of their AH maximal voluntary contraction. While holding this contraction, electrical stimuli (5x1ms pulses at 300 Hz) were applied to one of four-foot sole sites (great toe, 4^{th} toe, metatarsal or heel) at a "moderate-strong intensity" as rated by the participant. To visualize the reflex, we performed a spike triggered average on the AH electromyograph and recorded the amplitude and polarity of responses occurring between 50-70 ms (early latency), 70-110ms (middle latency), and 110-150 ms (late latency) following the stimulation. We compared the amplitude and polarity of reflex responses between stimulation sites.

Results: Both great toe and metatarsal stimulation resulted in a significant early latency excitatory reflex, followed by a significant middle latency inhibitory reflex. Additionally, the metatarsal reflex was prolonged, and continued its inhibitory reflex into late latency. Upon 4^{th} toe stimulation, a significant inhibitory response was identified during the middle latency. Finally, there was no reflex response upon heel stimulation.

Discussion/Conclusions: Our preliminary data suggests that the cutaneous evoked reflexes in AH from foot sole skin may be location dependent in the seated position, however the amplitude of these reflexes are not as prominent as those previously reported in other postural muscles in the leg. This information may provide insight into how AH may be modulated to contribute to balance during postural tasks.

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A COMPARISON OF LOWER EXTREMITY KINEMATICS BETWEEN MARKER BASED AND MARKERLESS MOTION CAPTURE SYSTEMS: A PILOT STUDY

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Introduction:

The resource-intensive nature of traditional marker-based motion capture systems limits opportunities for quantitative motion analysis. However, the advancement of markerless motion capture technology yields tremendous promise for accessible kinematic analyses beyond conventional research settings. Uplift (Uplift Labs, California, USA) is a mobile, dual-camera markerless motion capture system that performs 3D pose estimation and outputs kinematic measures. The purpose of this pilot study is to validate this novel two-camera markerless motion capture system against a "gold standard" marker-based motion capture system.

Methods:

Eight recreationally active individuals were recruited for this pilot study (4 male/4 female, mean (SD) age: 23.13 (2.93) years, height: 1.79 (0.10), mass: 73.31 (13.44) kg). The marker-based system (MB) was a 17 camera Qualisys Motion Capture system (Oqus 500 (Qualisys AB, Gothenburg, Sweden)) sampling at 100Hz. Forty retroreflective markers were placed on lower body landmarks according to the Plug-In Gait model. The markerless camera system (ML) utilized two iPad Pros 6th generation (Apple Inc., California, USA) positioned in front of the participant, 45° to the left and right of center. Participants performed three trials each of a squat and an alternating reverse lunge.

MB data were filtered using a zero-lag sixth order low pass Butterworth filter with a cutoff frequency of 3Hz and resampled to 60Hz. ML data were collected at 60Hz and filtered using a zero-lag fourth order low pass Butterworth filter with a proprietary cutoff frequency determined using residual analysis. Time series data were synchronized by aligning the peak left hip flexion value. Root mean square error (RMSE) was calculated for left and right hip, knee, ankle flexion and knee varus. RMSE values were averaged across all subjects to provide an indicator of the magnitude of measurement difference between the two systems.

Results: Mean RMSE values are presented in Table 1.

Discussion and Conclusions:

The RMSE values of knee flexion and knee varus suggest some fidelity between the ML and MB motion capture systems. However, the magnitude of all RMSE values indicates that further refinement of the present markerless motion capture system is required. Future validation work should consider more dynamic tasks such as jumping.

Table 1: Mean root mean squared error values of joint angles of the squat and alternating reverse lunge

	R-Hip flexion	L-Hip flexion	R-Knee flexion	L-Knee flexion	R-Knee varus	L-Knee varus	R-ankle flexion	L-Ankle flexion
Lunge	22.13	20.36	17.53	11.36	18.03	14.39	21.50	23.56
Squat	22.22	20.55	17.50	11.67	18.03	14.73	21.78	24.06

EFFECTS OF PROLONGED RAPID MOUSE AIMING ON MUSCLE FATIGUE AND MOTOR PERFORMANCE IN GAMERS AND NON-GAMERS

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Introduction: Esports are becoming increasingly popular, however, little research exists on the physical impact of the sport. Gaming is physically demanding, with many individuals reporting injuries [1] or experiencing pain and discomfort in their upper limbs while playing [2]. Investigating changes in forearm muscle activity as individuals' fatigue will provide critical insight into how muscular demands change during extended periods of gaming and how those changes may impact performance and long-term health of gamers. The purpose of this study was to evaluate muscle fatigue and performance impairments during an extended mouse aiming fatigue protocol.

Methods: Twenty participants were recruited for this study (8F, 12M), separated into gaming and non-gaming groups. Surface electromyography was measured from eight muscle of the right upper limb. Participants performed a 30-second mouse aiming task using aim training software (AimLab, State Space Labs, Inc., New York, New York, USA). To assess muscle fatigue, reference contractions of radial and ulnar deviation (30% of max) were performed throughout the experiment. Participants also provided ratings of perceived fatigue (RPF) throughout the experiment. The fatiguing protocol involved six, 5-minute bouts of hitting targets in AimLab. Performance and fatigue assessments were performed after each bout of AimLab fatigue. Mean power frequency (MnPF) and RMS amplitude were calculated during reference contractions to quantify muscle fatigue. Performance measures were calculated in AimLab and included total targets hit, accuracy, and error size.

Results: Gamers outperformed non-gamers, hitting 14.4% more targets during the performance task (Gamers: 67.5 ± 6.1 targets; Non-gamers: 59.0 ± 4.6 targets, $p=0.001$). However, no difference in accuracy or error size were found between gamers and non-gamers. No changes in performance measures were observed throughout the experiment. RPF increased in a linear fashion during the fatiguing protocol, reaching a maximum rating of 4.2/10 after 30-minutes. A decrease in MnPF was observed in the extensor digitorum communis (EDC) and extensor carpi ulnaris (ECU) during the radial reference contractions. MnPF of EDC and ECU were significantly lower at all time points following baseline, with a maximum decrease of 22.8% and 25.7%, respectively.

Conclusions: Changes in performance metrics indicate no impairments caused by the fatiguing protocol. RPF ratings reached 4.2/10 after 30-minutes, indicating participants felt substantial muscle fatigue. Decreases in MnPF indicate that EDC and ECU became significantly fatigued by prolonged mouse aiming, indicating the extensors are prone to gaming related fatigue and injury.

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DO RELATIONSHIPS BETWEEN KINEMATIC AND PERFORMANCE VARIABILITY MEASURES DURING OBSTACLE CROSSING CHANGE AS A FUNCTION OF AGE?

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Introduction: Tripping is a frequent cause of falling amongst older adults, and as lower limb mechanics continually change with age, the risk of injury from a fall increases [1]. Previous research has found that, during obstacle crossing, older adults exhibit greater foot clearances [1-2], reduced horizontal distances and crossing speeds [3-5], and increased hip flexion [6]. However, age-related changes in lower limb kinematic variability during obstacle crossing have been less-often investigated [7]. Joint-specific approaches have been adopted for examining kinematic predictors of performance measures (e.g., step length, step width) during gait, identifying an effect of age on the joint of greatest predictive value (hip and ankle for younger and older adults, respectively) [8]. However, this approach has not been applied for obstacle crossing, nor extended to variability of kinematic and performance measures.

Aim: To quantify age-related changes in kinematic predictors of variability in performance measures during obstacle crossing.

Methods: This study is a secondary analysis of data from 20 young adults (18-30 years) and 20 community-dwelling older adults (65-77 years), free of illnesses or conditions impairing gait performance [8]. Motion capture (Oqus 400+, Qualisys, IL, USA) was used to track full-body motion during five obstacle crossing trials, where participants stepped over a 0.20 m high obstacle. From the motion capture data, kinematic (flexion-extension and adduction-abduction joint angles of the hips, knees, and ankles) and performance (foot clearance, crossing speed, horizontal distance, postural stability) measures will be determined. Variability in kinematic measures will be quantified using cross-correlation and root mean squared error; variability in performance measures will be quantified using standard deviations. Relationships between these measures will be examined for each age group using linear regression, providing insight into the joints most closely associated with performance variability measures [7].

Expected results: We expect that kinematic variability at the ankle and hip joints will be more closely related to performance variability for older and younger adults, respectively. Findings will aid in identifying indicators of trip and fall risk for older adults during obstacle crossing, which may inform falls risk assessment and prevention strategies.

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RELIABILITY OF THE OPENCAP SYSTEM FOR DETERMINING KNEE KINEMATICS DURING SINGLE AND DOUBLE LEG REBOUND JUMPS

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Introduction: Mitigating injury risk and preventing injuries in sport is crucial for improving and maintaining athletic performance. In jump heavy sports, such as basketball, it is common for injuries to be sustained while landing [1]. Some sports also see high levels of single leg landings. These single leg landings typically have biomechanical detriments when compared to double leg landings, such as decreased knee flexion [2], [3], [4] or increased ground reaction force [3], [4]. Currently, there are no reliable ways to determine the quality of single leg landings. However, the Landing Error Scoring System (LESS) is a valid and reliable way of assessing the quality of double leg landings [5]. To develop a way of assessing the quality of single leg landings, a reliable method of collecting kinematic data from double and single leg landings needs to be established.

Aim: We aimed to determine the reliability of the OpenCap system (Stanford University, California, USA) in determining knee joint angle data during double and single leg rebound jumps.

Figure 1: OpenCap System sample recording (Stanford University, CA, USA)

Methods: A total of 30 participants will be recruited for this study, consisting of 15 competitive and 15 recreational athletes. Participants will be required to complete a total of 9 rebound jumps, based on the Landing Error Scoring System, following a standardized warmup. Specifically, participants will first complete a two-legged rebound jump from a 12-inch box, where they are to land at a target line placed in front of the box at half their height and immediately complete a rebound vertical jump for maximum height. Following these 3 bilateral jumps, they will also complete 3 single leg jumps for each leg in random order, all with 30 seconds rest between jumps. Two iOS devices (Apple iPad, 8th Generation), placed 5m apart on a line parallel and 4m from the rebound target line will record each jump through the OpenCap system (Stanford University, California, USA). The maximum knee flexion during the rebound and medial knee position, with respect to the foot, will be obtained from each of the 9 jumps, as well as the between limb asymmetry for single leg jumps. The reliability of these values will be determined independently with competitive and recreational athletes using an Intraclass Correlation Coefficient. Further, the sensitivity to between group differences in these metrics will also be examined using an independent t-test.

Expected Results: It is expected that knee kinematics from bilateral jumps will display excellent reliability (ICC > 0.9), while single leg and asymmetry knee kinematics will display good reliability (ICC > 0.75). However, we also expect that single leg and asymmetry knee kinematics may display greater sensitivity in discriminating groups, as compared to the bilateral knee kinematic data.

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COMPARING GLOBAL AND LOCAL RESPONSE OF THE LUNGS IN IMPACT HUMAN BODY MODELS

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Introduction: Finite element (FE) human body models (HBMs), including the thorax and lungs, are increasingly used to simulate impact scenarios, to evaluate injury risk which can be assessed using global (i.e. chest compression, velocity, accelerations, etc.) or local (i.e. tissue stress or strain) criteria. For HBMs incorporating the lungs, a common constitutive model for the lung tissue is the hyperelastic formulation from Vawter [1], for which a number of material parameter sets have been reported in the literature with a wide range of stiffnesses. A challenge for researchers using HBMs is to determine which parameter set to use, particularly for soft tissues such as the lungs, where material properties often encompass large variability.

Methods: All of the reported material parameter sets for the Vawter lung model from the literature were used in a thoracic pendulum impact simulation to compare their predictions of lateral chest compression (a global thoracic response metric) and lung tissue strains (a local tissue-level metric). A 5.6 m/s lateral impact to the right side was simulated using a contemporary HBM (WALT v5.3 [2], Figure 1a) and a commercial FE code (LS-DYNA R9).

Results: The chest compression predicted by the model did not demonstrate sensitivity to the various lung parameter sets (Figure 1b). In contrast, the strain magnitudes in the lung tissue elements demonstrated large differences depending on the parameter set (Figure 1c, showing the volume fraction of lung material exposed to strain).

Discussion and Conclusions: This study demonstrates the importance of selecting appropriate and biofidelic material properties for the lungs (and other soft tissues) when using local tissue-level injury criteria such as strain, since the magnitudes of local tissue response can vary significantly (Figure 1c), even though global metrics may not be sensitive (Figure 1b).

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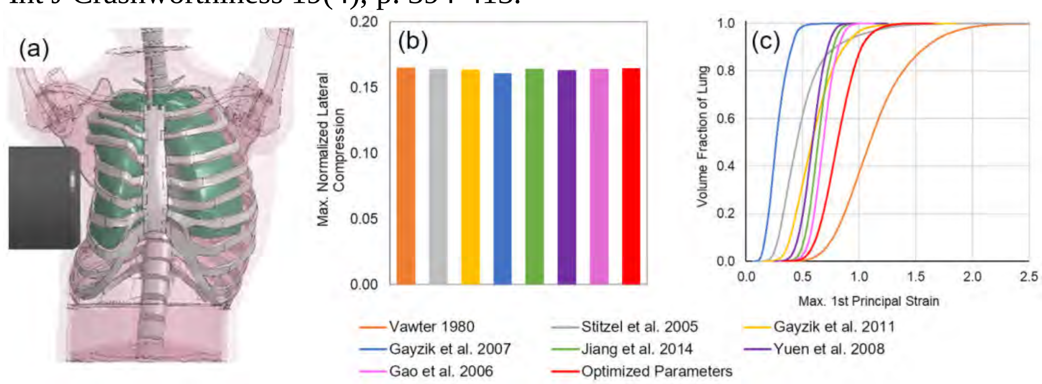

Figure 1: (a) Thoracic pendulum impact simulation with results of (b) chest compression and (c) right lung strains for various lung tissue constitutive parameter sets from the literature

EFFECTS OF TRUNK POSTURE ON LIFTING STRENGTH

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Introduction: Movement based interventions to manage low back exposure have targeted trunk inclination (i.e. posture of the trunk segment relative to vertical axis in the environment) and trunk curvature (i.e. lumbar spine posture) [1]. Trunk inclination and curvature each have distinct effects on tissue loading [2], but may also have unique effects on multi-joint force exertion (e.g. lifting an object from the ground) as trunk inclination and curvature can influence length dependent generation and transfer of muscle forces at the trunk as well as adjacent joints [3,4]. The effects of trunk inclination and curvature on the ability to exert force in a multi-joint movement may also interact. However, the interaction of trunk inclination and curvature on the ability to exert lifting force has not been thoroughly investigated.

Aim: Investigate the effects of trunk inclination and curvature on exerted isometric lifting force.

Methods: Isometric lifting force was measured across four lifting postures consisting of two trunk inclinations (vertical and horizontal), each performed with two trunk curvatures (neutral and flexed). Fourteen participants (target sample size 20 males and 20 females) assumed a vertical and horizontal trunk lifting posture while maintaining the same foot position. Real time video and optical motion tracking (Optotrak Certus system, Northern Digital Inc., Waterloo, ON, Canada) were used to cue participants into trunk curvatures between 20-30% (neutral condition) and over 80% (flexed condition) of their maximum low back flexion, as well as to control knee posture between trunk curvature conditions within each trunk inclination condition.

Expected Results: It was initially predicted that trunk inclination would have a greater influence on exerted lifting force than trunk curvature as changing trunk inclination would influence the lower extremity joints to a greater extent than changing trunk curvature. For instance, maintaining a vertical trunk requires more knee flexion to reach objects on the floor compared to lifting with a horizontal trunk. Whereas, changing curvature can be accomplished without changing knee posture. However, the data collected thus far shows that individual differences exist such that the effects of trunk inclination and curvature are not consistent between individuals. As data collection continues, it is possible that more consistent aggregate trends emerge. Alternatively, further analyses will aim to identify if there are biomechanical variables that explain these individual differences if no consistent trends emerge.

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RE-DISTRIBUTIONS IN MECHANICAL ENERGY EXPENDITURE CAUSED BY RESTRICTING SPINE MOTION DURING LIFTING

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Introduction: Lifting with, versus without, spine flexion requires less lower extremity motion [1], but effects on joint kinetics have not been documented. Thus, the impact of biomechanical constraints on lifting behaviour is unclear. The objective was to compare ankle, knee, hip, low-back, and total mechanical energy expenditure (MEE) between spine flexion-restricted and self-selected lifting. MEE was used as basis of comparison because it provides a high-level approximation of joint demands while reducing dimensionality of the data.

Methods: Twenty participants (10 female) performed a series of barbell lifting tasks that varied by three task factors: 1) spine posture (presence or absence of spine flexion-restricting harness); 2) lift origin height (high = knee height, low = mid shank height); and 3) object mass (light: females = 20kg; males = 34kg and heavy: females = 34kg; males = 58kg). Five repetitions for each combination of the task factors were performed. An optoelectronic motion capture system (VICON, Oxford, UK), and two spatially synced in ground force plates (AMTI BP400600-OP, MA, USA) were used to record segment mechanics during all lifts. Bottom-up inverse dynamics analyses were conducted using standard methods to quantify lower extremity and spine kinematics and kinetics, which were used to quantify absolute and relative MEE. Repeated measures ANCOVAs were used to compare all dependent variables between spine restriction, lift origin height, and object mass conditions.

Results: Figure 1 depicts results obtained for MEE. Total MEE was higher when lifting from a lower origin or a heavier mass (p <0.001). Joint-level MEE differences for the spine and hip, when lifting from a lower height, were greater when spine flexion was restricted (p <= 0.05). Similarly, the difference in MEE for the ankle between lift origin heights was greater for the heavier mass (p = 0.05). A lower height also increased MEE at the knee compared to a higher height (p <0.0001). On average, restricting spine flexion decreased the relative contribution of the spine to total MEE by 13%, which was countered by 12% increase in the relative contribution from the hips (p <0.001). The higher lift origin increased the hip's contribution to total MEE by 5% (p = 0.01). Conversely, the lower lift origin increased the ankle's contribution to MEE by 1% (p <0.001).

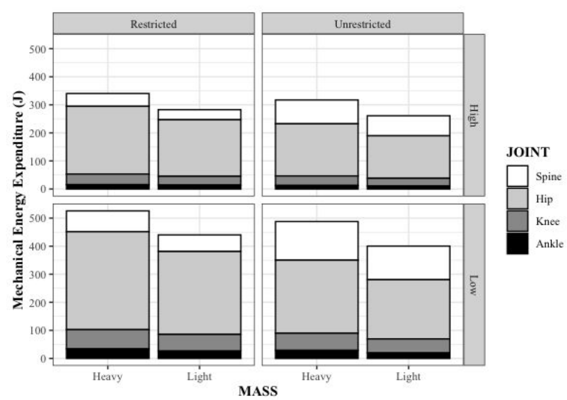

Figure 1: Total MEE depicted on the vertical axis, and stacked bars show contribution of MEE from each joint to the total in each lifting task.

Discussion and Conclusions: To reduce lumbar spine flexion during lifting, spine MEE appears to be redistributed to place even greater demands on the hips. This effect is further exaggerated when lifting objects from heavier masses, though not necessarily lower heights. Individuals lacking the capacity to meet further increases in mechanical demands on hips may be obliged to flex the lumbar spine when lifting, especially during increased task demands such as heavier or lower lifts.

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THE USE OF ULTRASOUND SHEAR WAVE ELASTOGRAPHY TO ESTIMATE THE MECHANICAL PROPERTIES OF SOFT TISSUES IN THE PROXIMAL FEMUR

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Introduction: Approximately 20-30% of older adults experience one or more falls each year, making fall-related injuries the leading cause of morbidity and mortality in this population [1]. A common injury caused by falls are hip fractures, which are associated with high rates of disability, medical costs, and mortality [2]. Soft tissue properties, such as thickness and muscle contraction, influence the distribution of force within the pelvis during an impact [3,4]. However, there are gaps in our knowledge of the mechanical properties of the soft tissues in the hip region. Shear wave elastography (SWE) is an ultrasound imaging technique that allows for the quantification of the shear wave velocity (SWV) of tissues within the body, which can also be used to compute their Young's modulus.

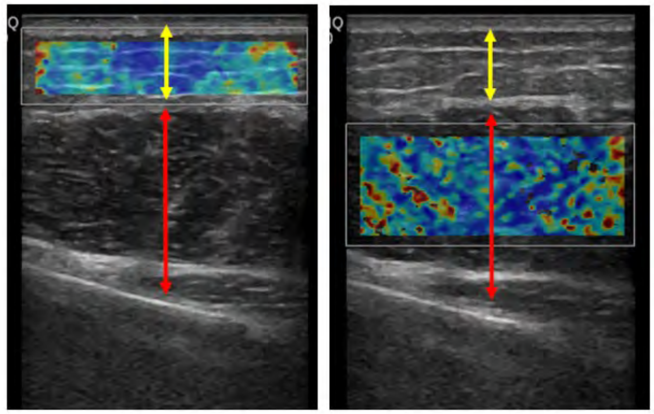

Figure 1: SWE of subcutaneous adipose (left) & gluteus maximus (right)

Aim: For the region principally loaded during sideways falls, this study aims to determine whether SWV of the subcutaneous adipose and muscle (gluteus maximus) are influenced by muscle contraction, to assess the intra-rater reliability, and to investigate whether the intra-rater reliability is influenced by muscle contraction.

Methods: Twenty healthy adults will be positioned on their right side with their hips and knees straight. Three SWV measurements of their adipose and muscle will be taken from the location of interest (Figure 1) while they are resting, using the GE LOGIQ E10 and a linear array transducer (GE Healthcare Canada, ON, Canada). Subsequently, three SWV measurements of these tissues will be taken while they contract the gluteus maximus to 60% of their MVC. A two-way repeated measures ANOVA will be conducted to examine the interaction effect of contraction state on the adipose and muscle tissues' SWV. A two-way mixed effect absolute agreement intraclass correlation (ICC) model will be used to assess the intra-rater reliability. Finally, a two-way repeated measures ANOVA will be conducted to assess the influence of contraction state on the reliability.

Expected Results: There will be an interaction effect of muscle contraction on the SWV magnitudes of the soft tissues. It is expected that the muscle's SWV will be greater during the muscle contracted trials compared to the resting trials, while the SWV of the adipose will remain consistent during both trials. The intra-rater reliability of the SWV measurements will be good to excellent (ICC > 0.75) in both tissues, and will not be influenced by muscle contraction.

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Poster Session B – Fed Hall Wed May 10 8:00 PM-9:00 PM		
1	Carl Alano Brock University	Automated Movement Screen: Developing A Data-Driven Scoring Tool To Assess Spine Motor Dysfunction
2	Katherine Athaide University of Guelph	Muscle Mechanics Associated With Vertebral Level
3	Maxwell Campbell Western University	The Sensitivity Of Bony Landmarks And The Scapholunate Interval To Wrist Malrotation In The Posteroanterior Radiograph
4	Ryuta Dharmaputra Ontario Tech University	Comparing Immersive Virtual Reality Systems For Ergonomics Assessments In Automotive Assembly Tasks
5	Heather Grandy University of Ottawa	Triple Jump Technique Assessment
6	Megan Hutter Western University	Developing Three-Dimensional Ultrasound For Blood Flow Assessment Of Thumb Osteoarthritis
7	Tamar Kritzer Brock University	Physical Demands In Helicopter Manufacturing
8	Larissa Madia Western University	The Role Of Transverse Plane Malalignment In Posterolateral Corner Complex Injury
9	Laura Marrelli University of Guelph	Skin Input, Rate Of Torque Development, And Fatigue
10	Alexis Napper Brock University	Physical Demands In Arborists
11	Luke Opilka Wilfrid Laurier University	Examining Hip Spine Syndrome
12	Eseoghene Orogun McMaster University	Smart Insole Validation For Assessing Foot Progression Angle
13	Kylie Paliani Western University	The Analysis Of Healthy Shoulder And Anatomic Implant Shoulder Glenohumeral Arthrokinematics
14	Noah Polesky Brock University	Forearm Muscle Activity During Eccentric Exercise
15	Xaysha Solomon Wilfrid Laurier University	Annulus Fibrosus Damage Following Disc Herniation
16	Jessica Wanyan Wilfrid Laurier University	Balance During Gait In Adult ADHD Population
17	Vanessa Yuan Brock University	Slips While Walking In Occupational Footwear
18	William Auray Ontario Tech University	The Effect Of Extended Reach On Manual Arm Strength And Hand Location Relative To The Shoulder

19	Joel Carriere University of Guelph	Wrist Kinematics Through Open Source Markerless Motion Capture
20	Hunter Carswell Nipissing University	Age-Related Changes In Spatiotemporal-Kinematic Relationships During Gait
21	Ryan Chhiba McMaster University	Hand Pressure Effects On Internal Loading
22	Sarah Fitzgerald Ontario Tech University	Exploring The Effects Of Mental Fatigue On Perceptual Motor Task Performance And Upper Limb Kinematics
23	Emma McArthur Nipissing University	Effects Of Age On Relationships Between Kinematics And Center Of Mass Motion During Gait
24	Livia Murray University of Waterloo	Short Time Fourier Transform For Gait Bout Detection In Free-Living Accelerometry
25	Gillian Phillips Queen's University	Effects Of Gait Variability On Adaptation To Ankle Exoskeletons
26	Elizabeth Zafar University of Waterloo	Role Of Low Back Capacity On Functional Movement
27	Rebecca Chan University of Toronto	Jump Type Effects On Lower Extremity EMG
28	Victor Chan University of Ottawa	EMG Wavelet And Complexity Analyses Of Fatigue
29	Benjamin Cornish University of Waterloo	Multiscale Entropy For Complex Lower Limb Accelerometry During Walking
30	Matheus Correia University of Waterloo	Optimized HBM Neck Activation In Lateral Impacts
31	Simon Friesen University of Waterloo	The Effect Of Hand Load Stability On The Recruitment Of Shoulder Stabilizing Musculature During Bench Press And Military Press V
32	Prasannaah Hadagali University of Waterloo	Effect of Rotary-Wing Aircrew Head-Supported Mass in Flexion Position on the Tissue-Level Response of the Neck: An FE Study
33	Dveeta Lal University of Toronto	Side To Side Diferences In Lower Extremity Fatigue
34	Jenna Pitman University of Guelph	Spatial Context Of Visual Information: Influence On Performance Of A Walking Turn
35	Emily Roberts University of Windsor	Head Impacts In Youth Hockey.
36	Julia Shannon University of Guelph	High Intensity Interval Training Vs Moderate Intensity Continuous Training In Parkinson’s Disease
37	Kathryn Webster University of Waterloo	The Influence Of Swim Bench Rotation Settings On Upper Body Kinematics And Muscle Activity Patterns In Simulated Swimming
38	Mitchel Whittal Wilfrid Laurier University	Cyclic Tensile Loading And IL-1β Stimulation

39	Prabhlin Aujla McMaster University	How Lumbar Spine Positioning Affects Clinical Diagnosis Of Osteoporosis And Dual-Energy X-Ray Absorptiometry Measures
40	Stefania DiLeo University of Toronto	Kinematic Outcomes After FAIS Treatment
41	Jason Hunter University of Waterloo	Subject-Specific Active Control Of A Stroke Rehabilitation Robot
42	Colin Dunne Brock University	Investigating Portable Instrumentation To Profile Kinematics And Plantar Pressure During On-Ice Starts
43	Fatima Gafoor McMaster University	Validation Of Physical Activity Levels From Shank-Placed Axivity Ax6 Accelerometers
44	Courtney Hlady University of Toronto	Hip Kinematics And Sport Specialization
45	Kate Krivenko University of Waterloo	Tablet And Computer Tasks Completed In Sitting And Standing
46	Jonah Leinwand University of Waterloo	A Novel Compliant Support Mechanism For Cervical Artificial Disc Replacement
47	Xinyi (Julia) Li University of Waterloo	Validation Of A 2D Video-Based Ergonomics Assessment Tool
48	Hailey Nestor University of Waterloo	Efficacy Of A Device To Reduce Neck Muscle EMG During NVG Use
49	Katarina Osojnicki University of Guelph	Relationship Between Sleep And Physical Activity In Preschool-Aged Children Over 1-Year
50	Sasha Renton De Lannoy University of Toronto	Lower Extremity Emg Mapping
51	Meera Sayal Brock University	Cross Education And Robotic Rehabilitation
52	Samantha Segal University of Guelph	Intervertebral Disc Degeneration In Menopause
53	Juliana Bossom University of Waterloo	Effects Of Female Sex Hormones On Lumbar Spine And Hip Passive Stiffness
54	Lia Tennant University of Waterloo	Diurnal Variation In Axial Lumbar Impacts
55	Malinda Hapuarachchi University of Toronto	Characterizing Vertical Jump Kinetics In Field Hockey Canada Development Pathway Athletes
56	Jordan Hobson University of Waterloo	Panoramic Compared To Site-Specific B-Mode Ultrasound Over The Lateral Hip
57	Aleksander Rycman University of Waterloo	Strains In The Cervical Spinal Cord

AUTOMATED MOVEMENT SCREEN: DEVELOPING A DATA-DRIVEN SCORING TOOL TO ASSESS SPINE MOTOR DYSFUNCTION

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Introduction: Low back pain (LBP) is the leading cause of disability worldwide, affecting over 500 million people annually across the globe [1]. Many of these cases (up to 90%) are classified as ‘non-specific’ [2], meaning that the pain cannot be attributed to any specific injury or pathology. It is understood that those affected by LBP present with highly heterogeneous motor control phenotypes that are indicative of dysfunction and pathological pain development [3]. By investigating range of motor control behaviours, it is believed that specific subgroups of dysfunction may be distinguished, which can help clinicians objectively administer a more personalized and effective standard of care [4]. As such, objective assessments of movement may help to streamline the management of LBP, but current methods of quantification, such as using a 3D motion-capture studio, can be costly and limit the practical use of the technology. As a result, the scalability and accessibility of these technologies in real-world settings is restricted. Recent advancements in computer vision and smartphone availability have made human motion capture more accessible. Specifically, deep convoluted neural networks (DCNN) have enabled efficient tracking of body parts and movement behaviors with 2D camera inputs (i.e., pose estimation).

Aim: The study aims to leverage open-source human pose estimation software (MediaPipe™, Google) to understand the relationship between motor patterns derived from cell-phone inputs, and participant reported outcomes related to low back dysfunction.

Methods: To address this aim, we have proposed sampling 1000 participants into an online study (190 currently sampled to date)). Participants enrolled in the online study will complete validated questionnaires related to disability (Oswestry Disability Scale, Quebec Disability Scale), fear of movement (Tampa Scale for Kinesiophobia), and physical activity (International Physical Activity Questionnaire), while also uploading videos where they complete standardized movement tasks (i.e., object pick-up, squatting, spine flexion). Pose data from the spine movement trials will be processed and reduced using principal components analysis (PCA) to facilitate input into a supervised machine learning framework. Specifically, spine movement features (principal components) will be used as inputs to predict functional outcomes related to disability, fear of movement and physical activity history.

Expected Results: Many previous research studies have distinguished motor features between those with/without LBP. It is hypothesized that principal components derived from the movement pose data will be capable to objectively discriminate levels of motor dysfunction throughout the large sample of participants. This research will lay the foundation for future work leveraging these data as inputs into supervised and unsupervised machine learning models to facilitate the objective classification of LBP related disability, and the potential presence of clinically relevant subgroups.

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INVESTIGATING CONTRACTILE AND STRUCTURAL PROPERTIES OF RAT PARASPINAL MUSCLES AT DIFFERENT VERTEBRAL LEVELS

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Introduction: Paraspinal muscles are imperative to the functionality and health of the spine. It is known that stresses to the spinal environment lead to alterations in paraspinal muscle structure and function [1], which may to contribute to the disease process [1]. To understand the nature and distribution of loads on the spine, musculoskeletal models that incorporate paraspinal muscles are utilized. These models have assumed that paraspinal muscles possess similar mechanical and structural properties independent of vertebral level. A previous study has shown that this assumption is valid for passive mechanical properties of paraspinal muscles [2]; however, it is unknown if this is also true for active contractile properties. Therefore, the purpose of this current work is to investigate if differences in muscle contractile function and architecture exist amongst multiple vertebral levels.

Aim: To investigate possible differences in active contractile and structural properties of paraspinal muscles at the thoracic, thoracolumbar, and lumbar vertebral levels.

Methods: Muscles will be obtained from mature female and male control Sprague-Dawley rats following euthanasia. Single muscle fibres will be isolated from multifidus and erector spinae groups at thoracic, thoracolumbar, and lumbar vertebral levels. The contractile function and force-sarcomere length properties of the fibres will be tested using a force transducer and high-speed motor (Aurora Scientific). Structural analysis will be done using histological techniques including hemotoxalin and eosin (H&E) and picrosirius red stains to assess muscle morphology and collagen distribution, respectively.

Expected Results: It is expected that there will be no differences between the three vertebral levels being investigated. Therefore, there will be no distinctions between muscles when testing specific force (sF_o), average optimal sarcomere length, and rate of force redevelopment (k_{tr}). Additionally, histological evaluation of muscle composition will show there are equivalent amounts of collagen, regardless of level. If true, these results will aid in the validation of current approaches used for developing musculoskeletal models of the spine, as well as provide insight into vertebral level-specific muscle data obtained from surgical intervention studies.

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THE SENSITIVITY OF BONY LANDMARKS AND THE SCAPHOLUNATE INTERVAL TO WRIST MALROTATION IN THE POSTEROANTERIOR RADIOGRAPH

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[2] Roth McFarlane Hand and Upper Limb Centre, London, ON
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Introduction: Scapholunate ligament instability (SLI) is the most common carpal instability [1], which left untreated may contribute to a form of progressive arthritis recognized as scapholunate advanced collapse. Clinicians use the scapholunate (SL) diastasis to diagnose potential SLIs and is measured from the posteroanterior (PA) radiograph of the wrist. It is difficult to get a consistent PA radiograph given limited hand and wrist range of motion in the presence of injury and disease and also from technical factors, including a need for more understanding regarding patient positioning and clinical applications. This can lead to unrecognized errors in the measurement of carpal indices, which could cause misdiagnosis or errors in the treatment of these injuries. Previous work has shown that carpal indices are sensitive to rotational malpositioning in the lateral radiograph, but little work has been done focusing on the PA. This study aims to determine the effect wrist malrotation has on the measured SL diastasis and four proposed bony landmarks in the PA radiograph.

Methods: Eleven healthy fresh-frozen cadaveric wrists were radiographed in the "expert neutral" PA position. Expert neutral in this study was defined as the amount of pronation required to compensate for the wrists thenar eminence, placing the wrist frontal plane perpendicular to the incident x-ray beam. Using custom positioning wedges, specimens were rotated and imaged from 30° of pronation to 30° of supination in 10° intervals. In each radiograph, measurements of the scapholunate diastasis, as well as the following landmarks: (1) the visible perimeter of the base of the hook of the hamate, (2) the radial-ulnar distribution of the dorsal non-articular surface of the distal third-metacarpal head, (3) the radial-ulnar distribution of the pisiform about the longitudinal axis of the ulna, and (4) the overlap of the pisiform and triquetrum, were taken.

Results: The measured SL diastasis was largest within the expert neutral frame and linearly decreased by 34.48% for every 10° of pronation and decreased non-linearly by 86% for the first 10° of supination and a further 6% at 20° of supination. The distribution of the distal third metacarpal head was shown to be sensitive to both pronation and supination. The perimeter of the hamate, as well as the distribution of the pisiform, were both shown to be sensitive to supination, whereas the overlap of the pisiform was not shown to be sensitive to either direction of rotation.

Discussion: These results exhibit the sensitivity of the SL diastasis to wrist pronation and supination within the PA radiograph. Using the proposed landmarks, clinicians can identify malrotated PA radiographs, reducing the unrecognized error in the measurement of carpal indices and, thus, the rate of misdiagnoses. These results motivate the importance of proper wrist positioning during PA radiographs to improve the detection of SL ligament-related injuries.

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COMPARING IMMERSIVE VIRTUAL REALITY SYSTEMS FOR ERGONOMICS ASSESSMENTS IN AUTOMOTIVE ASSEMBLY TASKS

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Introduction: Immersive virtual reality (VR) is a promising modality to proactively conduct ergonomics evaluations in challenging environments. Current VR systems allow integration of high-fidelity motion capture to improve the realism of VR immersion. Compared to reactive approaches, modifying design parameters in VR can help reduce musculoskeletal disorder risk factors and production costs [1]. However, more research is needed to determine how simulation parameters and different VR systems can affect the ergonomics evaluations being conducted.

Aim: The purpose of this study is to evaluate how different virtual reality systems and limb-modeling methods affect biomechanical variables in immersive automotive assembly task simulations.

Methods: Sixteen participants (8F, 8M) will be recruited from a convenience sample. Participants will be instrumented with reflective markers and a head-mounted display (HMD). Three VR HMDs will be assessed: HTC Vive Pro 2 (HTC Corporation, Taoyuan, Taiwan), Valve Index (Valve Corporation, WA, USA), and the Meta Quest 2 (Meta Platforms Inc., CA, USA). Upper limb and low back joint angles and moments will be calculated using VICON Nexus (Vicon Motion Systems, Ltd., Oxford, UK) and Tecnomatix Process Simulate 17.0 (Siemens Digital Industries Software, TX, USA). Kinematic accuracy will be assessed by comparing VR conditions to a no-VR control. A mixed effects model will be used with HMDs and fidelity of avatar perspective as fixed effects for shoulder moment, trunk flexion angle, and spinal compression.

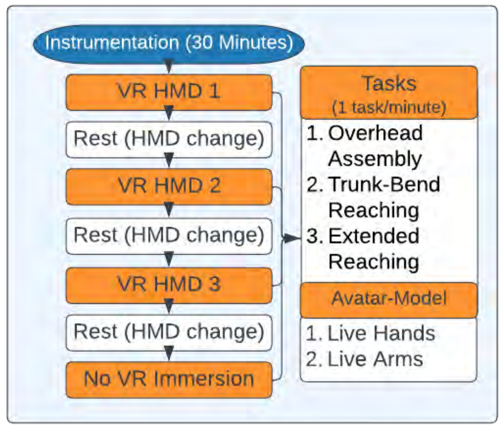

Figure 1: Experimental Protocol and Procedure

Expected Results: Based on previous literature [2], we anticipate that shoulder moment and joint angles will increase in wired VR systems, as well as a hands-only avatar model, compared to the wireless HMD. In addition, we hypothesize that kinematic accuracy will be greatly influenced when wearing all HMDs during trunk-bending reach tasks, regardless of avatar model. These results can help ergonomists conduct virtual proactive ergonomics assessments with confidence that these results would translate to real world environments.

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RUN FAST, JUMP FAR: OBJECTIVELY EVALUATING TRIPLE JUMP TECHNIQUE USING MARKERLESS MOTION CAPTURE

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Introduction: Triple jump is a highly complex track and field event that demands exceptional acceleration, preservation of velocity, and timing as athletes execute the hop, step, and jump phases [1-2]. Identifying specific movement patterns required to improve performance can be challenging for coaches and athletes, warranting the consideration of quantitative feedback mechanisms. Existing research has employed various biomechanical analyses and simulations to evaluate triple jump technique, but often with very small sample sizes [3]. Further, few, if any, have leveraged recent advancements in markerless motion capture to conduct data collection outside of a lab setting. This study aims to address these limitations in an effort to provide a more accurate representation of triple jump performance and to potentially detect variations in technique that were previously overlooked.

Aim: Using markerless motion capture technology, this study aims to measure key biomechanics metrics for triple jump and to employ machine learning and deep learning techniques to identify which features are the most significant predictors of performance in the event.

Methods: The study will recruit a minimum of 15 female and 15 male triple jumpers as participants from a local track and field club. *Baumer* cameras (*Baumer*, United States) with *Contemplas* motion analysis software (*Contemplas*, Germany) combined with *Theia3D* markerless motion capture software (*Theia Markerless*, Canada) will be used to collect and analyze six full triple jumps performed by each consenting participant. Important indicators of triple jump performance, such as approach velocity, take-off angle, and flight time in each phase, will be calculated in the sagittal plane. These data will be used as input into a machine learning pipeline to determine the most influential features on triple jump performance, where the known variable is jump distance. The descriptive metrics along with outputs of the machine learning model will be reported in a mobile application.

Expected Results: This study will validate the *Theia3D* system's ability to capture the complexities of triple jump in a real-world setting. Upon successful data collection, machine learning and deep learning techniques will identify the most critical features impacting performance. These findings will be consolidated into a user-friendly mobile application to assist coaches and athletes in objectively assessing triple jump performance.

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DEVELOPING THREE-DIMENSIONAL ULTRASOUND FOR BLOOD FLOW ASSESSMENT OF THUMB OSTEOARTHRITIS

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Introduction: The first carpometacarpal joint (CMC-1) is an important joint in the thumb and a common site of hand osteoarthritis (OA) [1]. OA is a degenerative disease with an important component being inflammation, specifically of the synovium [2]. Recently, there has been an increased understanding of the role of inflammation in OA pathogenesis, with inflammation and angiogenesis being integrated processes. The role of angiogenesis and synovial hypervascularization in disease progression and development has not been fully understood. Ultrasound (US) is an imaging modality used to assess musculoskeletal diseases and can visualize blood flow with Doppler technologies such as power Doppler (PD) and superb microvascular imaging (SMI) [3]. Positive Doppler signal in the joint is an indicator of active joint inflammation and can be graded semi-quantitatively. Conventional 2D Doppler ultrasound is limited to representing 3D anatomy and vasculature in 2D, is operator dependent and semi-quantitative.

Aim: To develop a 3DUS device with Doppler technologies to image synovial blood flow in CMC-1 OA.

Methods: The 3DUS device was developed to image with PD and SMI technologies. 3DUS PD and SMI images were acquired from one CMC-1 OA patient using a Canon Aplio i800 US machine (Canon Medical Systems Corporation, Otawara, Tochigi, Japan) with a 14L5 linear transducer attached to the semi-submerged 3DUS imaging system. The synovial tissue volumes were segmented. PD and SMI Doppler signal voxels within the segmentations were automatically counted. To further optimize the scanning parameters, we varied the solution temperature. 3DUS SMI images were acquired of the thumb region of a healthy volunteer at 22, 26, 30, 34 and 38˚C. Blood vessels surrounding the joint were segmented, and SMI signal voxels were counted.

Expected Results: Acquired 3DUS images showed Doppler signals within the synovial tissue volume with PD and SMI and voxel counts were determined. The pilot study demonstrated the capability of the system to detect and quantify the synovial tissue blood flow in the 3DUS images. 3DUS SMI images of the healthy volunteer showed an increase in SMI Doppler signals with increased temperature in the vessels surrounding the CMC-1 joint. This work demonstrated 3D quantification of SMI signals within blood vessels and assessed blood flow changes with temperature.

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ASSESSMENT OF UPPER EXTREMITY PHYSICAL DEMANDS IN HELICOPTER MANUFACTURING TASKS

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Introduction: Globally, workplace design prioritizes prevention of work-related musculoskeletal disorders (WMSDs), which represent a third of all sick leaves [1]. A growing world population and societal development generates high demand for air travel, resulting in an exponential growth of the aviation industry [2]. Composites and textile reinforcement materials (i.e., carbon fiber) has become popular for aerospace manufacturing. Composites account for over 50% of the structural weight [3]. Helicopter manufacturing involves repetitive manual tasks with largely unknown force requirements. Known risk factors for WMSDs common in helicopter manufacturing include awkward sustained postures, reaching, forceful exertions, and exposures to vibration, heat or cold [4]. The purpose of this study was to quantify physical demands associated with helicopter manufacturing tasks and evaluate how demands change as a function of different tasks.

Methods: Twenty healthy, university-aged females completed a series of trials replicating common helicopter assembly tasks (Figure 1) within a laboratory setting. Three tasks with two trials each were completed replicating smoothing composite layers onto concave (pod), convex (oil cooler (OC)), and flat molds (runner). A force transducer (Desnete, Guangdong, China) recorded reaction forces of the thumb during the tasks. Using a 10-camera optoelectronic (VICON, Oxford, UK) motion capture system, joint kinematics of the torso and right upper extremity were tracked from surface markers. Surface electromyography (sEMG) (Bortec, Calgary, AB) examined muscle activity of 16 muscles of the trunk and right upper extremity. sEMG data were analyzed as amplitude probability distribution functions (APDFs) normalized to muscle specific maximums, with the 10/50/90th percentiles extracted for further analysis.

Figure 1. Representative posture for cargo pod task.

Results: Results from the 50th percentile APDFs show the forearm muscles had the greatest muscle activity, with largest activities occurring during the runner task. The flexor carpi ulnaris and extensor digitorum superficialis resulted in mean sEMG amplitudes of 14.0±8.5% MVC and 22.1±6.3% MVC for the OC, 18.9±8.3% MVC and 26.7±9.9% MVC for the pod, and 24.4±13.9% MVC and 40.1±17.2% MVC for the runner task, respectively. The OC trial caused high mean upper trapezius, anterior deltoid, and medial deltoid activation at 18.1±6.7, 8.2±3.7, and 8.7±3.5.

Discussion and Conclusions: Parts layup relies heavily on the skill and experience of operators, resulting in considerable labour hours and material costs [5]. APDF outcomes exceed ergonomic guidelines for activation and warrant additional investigation of forearm demands. Future analysis of postures and force exertions will provide a complete picture of the physical demands associated with common helicopter manufacturing tasks, such that recommendations can be established.

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The Role of Transverse Plane Malalignment in Posterolateral Corner Complex Injury

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Introduction: The posterolateral corner (PLC) complex was previously referred to as "the dark side of the knee" due to the limited knowledge surrounding its anatomy, biomechanics, and treatment outcomes when injured. Over the past two decades, research efforts have improved the understanding of the PLC structure and have led to the development of biomechanically validated surgical reconstruction techniques. The PLC consists of three primary static stabilizing structures: the lateral collateral ligament (LCL), the popliteo-fibular ligament (PFL), and the popliteus tendon. These structures constrain external tibial rotation, posterior tibial translation relative to the femur, and varus angulation [1]. PLC injuries comprise approximately 16% of all ligamentous knee injuries and are often associated with multi-ligament tears [2]. Failure to address PLC injury is a contributing factor in knee instability, dysfunction, and likelihood of graft failure following cruciate ligament reconstruction [3]. Tibial torsion, which is a tibial deformity resulting in twisting of the tibia along the longitudinal axis, is an important contributor to gait abnormalities and knee malalignment [4]. It is theorized that an abnormal tibial torsion causing an externally rotated neutral position may subject the PLC to increased stress, increasing the susceptibility of this complex to injury.

Methods: Biomechanical cadaveric testing will be utilized to investigate the role of external tibial torsion in PLC complex loading, and ultimately in knee instability. Various methods of obtaining *in situ* forces and force distributions within the PLC during physiological conditions are under consideration, such as the use of a buckle transducer which will contact the PLC complex directly, or resection and superposition techniques which can indirectly estimate *in situ* tissue loads. The AMTI VIVO, a six degrees of freedom joint motion simulator, will be used to apply joint loads and motions replicating clinical stability tests and activities of daily living (such as gait). Torsional deformities of varying magnitude will be simulated by rotating the tibia with respect to the femur and the tibial fixturing. Cadaveric specimens will be tested in dynamic loading conditions with applied varus, rotational, and hyperextension stress, both with and in the absence of simulated external tibial torsion. Changes in PLC complex loads will be recorded.

Anticipated Results: It is hypothesized that the PLC complex will experience increased forces when the knee joint is subjected to external tibial torsion.

Discussion: This investigation is important to solidify a relationship between tibial torsion and injuries of the PLC in order to provide evidence for surgical decision making and prevent the onset of conditions that result from articular cartilage degeneration such as patellofemoral syndrome and osteoarthritis.

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THE FATIGUED AND THE FURIOUS: DOES SKIN STIMULATION MITIGATE FATIGUE-INDUCED REDUCTIONS IN RATE OF TORQUE DEVELOPMENT? A PROPOSAL

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Introduction: Performance fatiguability can be described as a transient exercise induced reduction in force generating capacity of the neuromuscular system. Rate of torque development (RTD), the speed at which an individual can generate joint level torque is reduced in the fatigued state. Reductions in RTD, specifically in lower-limb muscles, are associated with reduced ability to recover from postural perturbations, such as slips, as seen in older adults [1]. As such, improving RTD is important to aid balance and reduce injury risk. Cutaneous electrical stimulation over the hand has been shown to preferentially increase excitability of high-threshold motor units [2], which may produce force more rapidly than lower threshold units. Thus, cutaneous stimulation of the foot may increase RTD during voluntary contractions of the plantar flexors. Our previous work showed that cutaneous stimulation does not improve RTD in unfatigued muscles. However, it remains unclear if cutaneous stimulation can mitigate the decline in RTD observed following fatigue.

Aim: Assess whether cutaneous stimulation can mitigate the decline in RTD that is observed in fatigued muscle.

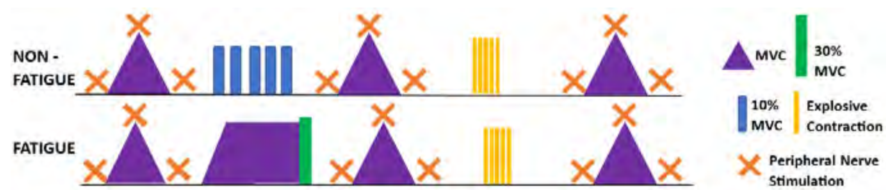

Figure 1: schematic of fatiguing protocol

Methods: While seated on a HUMAC NORM dynamometer (CSMi, Stoughton, MA, USA) healthy, young males and females will perform isometric plantarflexion contractions, "as fast and hard as possible", both with and without stimulation to test plantarflexion RTD. These contractions will be performed with the fresh, rested muscle as well as following a fatiguing protocol. Fatigue will be induced by sustaining a maximum voluntary plantarflexion, until the participant can no longer sustain 30% of their maximum. Two foot sole stimulation sites will be tested, heel and metatarsal, on separate days.

Expected Results: It is hypothesized that cutaneous stimulation will mitigate fatigue induced decreases in RTD by allowing higher-threshold MUs to be accessed despite reductions in voluntary central drive. Improving RTD may inform clinical interventions aimed at improving motor function in clinical populations. Such interventions may help improve standing balance and ultimately, quality of life in such populations.

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QUANTIFYING VIBRATION EFFECTS ON FOREARM EXPOSURES FROM COMMON ARBORIST EQUIPMENT

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Introduction: Work-related musculoskeletal disorders (WMSDs) are closely associated with posture, force, repetition, and vibration exposure. Forestry and agriculture workers are exposed to all four of these risk factors. Chainsaws decrease force requirements and repetitions for arborists but produce high-frequency vibrations; individuals with prolonged chainsaw vibration exposures are predisposed to hand-arm vibration syndrome and carpal tunnel syndrome [1]. Previous research has identified correlations between vibration intensity and increased muscular activation which may be a contributing factor to localized WMSDs [2]. Vibration research typically involves whole-body vibration or small power tools at a single intensity; little research exists examining localized vibration in industrial-scale power tools. Determining these localized vibration effects and how posture influences vibration transmission is essential in creating industry standards for exposure.

Aim: To quantify the influence of tool vibration on forearm muscle activity and upper extremity posture using common arborist equipment.

Methods: Surface electromyographic (sEMG), kinematic, and accelerometry measures will be collected to quantify muscular activation, posture, and localized vibration transmission. Participants will be drawn from active arborists with Ontario Chainsaw Certifications. sEMG will be collected from three wrist flexors and three extensors (Bortec AMT-8 (Bortec Biomedical, Calgary, AB). Series 3 accelerometers (NEXGEN Ergonomics, Point Claire, QC) will be secured to the tool and hand to measure vibration transmission. Joint angles will be recorded using motion capture. Participants will perform 2 repetitions of four typical chainsaw cutting tasks; individual trials will be 5-15 minutes in length as determined by task requirements. Between trials, ratings of perceived exertion and a two-minute precision test battery will be performed to examine longitudinal changes. sEMG outcome measures will include normalized muscular activation and EMG frequency characteristics. Vibration attenuation will be quantified using differences between accelerometer sensors to develop damping coefficients. Within- and between-trial joint angle changes will be recorded to examine technique changes. Following data processing, a mixed-model ANOVA will be performed using IBM SPSS Statistics (v.28.0.1.1) to quantify significant differences in activation patterns and vibration responses.

Expected Results: We hypothesize that sustained or high intensity vibration will significantly affect muscle activity and fatigue metrics. It is expected that root mean square sEMG will increase with a decrease in mean power frequency. Sustained vibrations will lead to significant performance decreases in the precision test battery and increases in ratings of perceived exertion by the end of the collection protocol. These findings will be used to provide critical insight into vibration effects on localized muscle activation and fatigue in the distal upper extremity, both of which are dominant risk factors for WMSDs. The current scarcity of knowledge surrounding vibration effects for these workplace tasks will quantify risk factors for arborists while having broader application to industrial workers where hand tool vibration presents as an exposure risk factor.

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THE EFFECT OF HIP SPINE SYNDROME ON THE MECHANICAL INTEGRITY OF THE ANNULUS FIBROSUS

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Introduction: The term hip spine syndrome is used to describe patients who have coexisting hip and spinal disorders. While there are three sub groupings that have been proposed for hip spine syndrome, the present study is particularly interested in secondary hip spine syndrome, defined as low back pain (LBP) caused by hip abnormalities.[1] Hip disorders that can lead to LBP can be classified biomechanically as hip extension limiting, hip flexion limiting, or a combined limitation.[2] These limitations in pelvic range of motion often necessitate a compensation in the lumbar spine region, leading to increased ranges required of the spinal motion units and subsequent injury.[2] While increased flexion range of motion have been linked to increased rates of herniation, there is a paucity of research examining how flexion and extension may affect the adhesive properties of the interlamellar matrix of the annulus fibrosus (AP). A recent study by Briar et al., found that static flexion negatively influenced the adhesion strength of the interlamellar matrix of the AP, regardless of sample location.[3]

Aim: The aim of this study is to investigate how cyclical flexion and extension of a functional spinal unit influences the adhesive properties of the interlamellar matrix.

Methods: Cervical porcine spine will be used; specifically the C3/4 and C5/6 will be excised from the cervical spines and randomized into one of three experimental conditions. The three conditions will be designed to mimic the spinal compensation found in hip spine syndrome; 1) cyclical spinal flexion, 2) cyclical spinal extension, and 3) combined cyclical flexion and extension. Following mechanical loading, the intervertebral disc will be dissected out and multi-layer samples of both the posterior and anterior AF will be extracted. The multi-layer samples will then be loaded onto a UStretch device (Cellscale Inc., Ontario, Canada) and will undergo a 180° peel test to determine the adhesion strength of the interlamellar matrix.

Expected Results: It is anticipated that microtrauma induced by the repetitive motions will cause decreased adhesion strength opposite the plane of motion. In the cyclical spinal flexion condition, it is expected to see a greater decrease in the adhesion strength of the posterior AF. The opposite effect is expected in the cyclical spinal extension condition. The combined cyclical flexion and extension group will likely see similar effects in both the anterior and posterior AF.

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SMART INSOLE VALIDATION FOR ASSESSING FOOT PROGRESSION ANGLE

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Introduction: Knee Osteoarthritis (KOA) is one of the most prevalent degenerative joint diseases, affecting almost 10% of adults aged 65 and over [1]. While there is no cure, many effective non-invasive treatment options have been limited by the requirement of laboratory-based motion capture equipment [2]. One of these non-invasive treatment options include the modification of the foot progression angle (FPA), which is a measure linked to reducing the knee adduction moment (KAM), and potentially slowing the progression of KOA [1]. In response to the limitations found when trying to monitor FPA outside of a lab setting, PROVA Innovations Ltd. has designed a Smart Insole + Biofeedback device to reinforce gait retraining in a home-based or out-of-clinic environment. PROVA's insole uses integrated force and inertial data to collect more robust positioning of the foot during all phases of gait. However, there is a need to directly assess the accuracy of the foot progression angle assessment.

Aim: The purpose of this study is to determine whether the PROVA Smart Insole accurately measures foot progression angle and other additional gait parameters, by comparing it against a gold standard, the Xsens Motion Capture System.

Methods: Healthy adult participants will undergo three 30-second walk tests, while wearing the motion capture devices. The primary variable being observed will be toe-out angle, to quantify FPA, while secondary variables will include step count, step time, gait speed, and sagittal foot angle at heel strike and toe-off. The Xsens Motion Capture system will make use of 8 integrated wireless sensors placed on key segments of the lower limbs. PROVA Innovations' Smart Insole will be worn within the participant's shoe concurrently with the Xsens system's sensors. Both devices will collect data independently during the walking tests and all the variables of interest will be separately computed for comparison. The relative and absolute validity of the PROVA insole will then be assessed using Pearson correlations coefficients and Bland and Altman plots with 95% confidence intervals, respectively.

Expected Results: We expect the PROVA Smart Insole to show a mean absolute error of approximately 3˚ for foot progression angle, as well as correlations >0.85 and 95% limits of agreement within 5˚. These findings would demonstrate the PROVA Smart Insole has sufficient measurement accuracy to progress the insole towards gait retraining trials.

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The Analysis of Healthy Shoulder and Anatomic Implant Shoulder Glenohumeral Arthrokinematics

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Introduction: The shoulder is the most mobile joint in the human body, enabling people to move their arms freely in many directions [1]. The shoulder consists of three bones: Humerus (i.e., upper arm bone), Scapula (i.e., shoulder blade) & Clavicle (i.e., collar bone), which make up the four shoulder joints: Glenohumeral (GH), Acromioclavicular (AC), Sternoclavicular (SC), and Scapulothoracic (SC) [1]. Due to the shoulder's ability to perform a wide range of motion (ROM), there is an incredible amount of stability lost, leading to numerous major shoulder injuries (e.g., Osteoarthritis), which result in shoulder replacements [2]. One common type of shoulder implant is an anatomic shoulder implant, which matches the normal anatomy of the shoulder (i.e., the humeral head component of the implant is placed directly where the original humeral head is located in the body) [3]. In obtaining an anatomic shoulder implant, patients hope to regain full range of motion (ROM) back at their shoulder, but some are just not so lucky, and struggle with simple daily activities like scratching/washing their back, getting dressed (e.g., tucking in shirts and/or putting on a bra) or even managing toileting [4]. This is hypothesized to be due to shoulder implants allowing for movement primarily in rotation, not in translation, which particularly restricts movement in the internal rotation (IR) to the back (i.e., reaching the arm from the stomach around to the back).

Methods: Four-dimensional computed tomography (4DCT) scans of 15 young and 15 old patients (n=30), as they completed the IR to the back movement were taken in healthy patients to benchmark what 'normal' ROM would be in the standard population. 4DCT, a new imaging modality only recently used in musculoskeletal (MSK) research [5], consists of capturing volume sequences (3DCT) over time to create a dynamic volume set, allowing us to see shoulder motion over the entire IR to the back movement [6]. These 4DCT scans were then inputted into 3D Slicer, which is a program that allows models of the exact shoulder anatomy of the patient to be made. Analysis of joint space area (JSA), joint congruency, and arthrokinematics, were conducted to define the age-related differences in glenohumeral arthrokinematics.

Results: It was found that the highest GH joint contact occurred near the beginning and end of the IR to the back movement for all patients. Overall, there was around 5.75mm (14.66%) of translation in the Superior/Interior (S/I) direction, and 3.33mm (10.91%) of translation in the Anterior/Posterior (A/P) Direction. It was also noted that younger patients had more translation in S/I direction and older patients had more translation in the A/P direction.

Discussion: In discovering the normal GH arthrokinematics in healthy individuals, it allowed us to quantify how much translation is needed to obtain normal range of motion in the shoulder. Next, we will repeat the same analysis for individuals with anatomic shoulder implants. After seeing how the GH joint moves differently with the implant in, we hope to be able to draw important conclusions regarding optimal conditions for anatomic implants, by looking at how various implant mismatches and different types of erosion also affect overall shoulder movement and glenohumeral implant tracking. Ultimately, we are hopeful that this research will allow people to live a normal life after shoulder implantation, free of restrictions.

EXAMINING THE EFFECT OF RESISTANCE LEVEL AND EXERCISE SELECTION ON FOREARM MUSCLE ACTIVITY USING THERABAND FLEXBAR

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Introduction: Lateral epicondylitis is a common tendinopathy that affects approximately three percent of the population annually [1]. Research has shown that eccentric exercise for the wrist extensors can be an effective treatment strategy. One such exercise, the Tyler Twist, was designed to target eccentric loading of the wrist extensors using Theraband® FlexBar (Performance Health, Akron, OH, USA) [2]. It remains unclear how various FlexBar resistances influence muscle activity. The purpose of this study was to use surface electromyography to measure forearm muscle activity while performing two eccentric loading exercises across four FlexBar resistance levels.

Methods: Thirty healthy participants (15M, 15F) performed two exercises (alternating twist and Tyler Twist) using four Theraband® FlexBars of varying thickness (increasing order of resistance = yellow, red, green, blue), creating eight experimental conditions. Surface electromyography of seven forearm muscles (flexor carpi ulnaris, flexor digitorum superficialis, flexor carpi radialis, extensor carpi ulnaris, extensor digitorum communis, and extensor carpi radialis brevis and longus) were recorded using wireless Trigno Quattro™ sensors sampled at 2222 Hz (10-850 Hz, Delsys, Natick, MA, USA). Muscle specific maximal isometric contractions were performed and used to normalize muscle activity as a %MVC for each condition. The average and peak muscle activity across 5 repetitions was calculated for each condition.

Results: For males, EDC had a significant main effect of FlexBar with activity increasing across resistance level (range 15.7-23.6% MVC) (Figure 1). FCU, FDS, FCR, ECR, EDC, and ECRl had significant main effects of exercise. For females, a significant main effect of exercise was found for all muscles. ECRb and EDC had a significant effect of FlexBar (range 6.8-27.5% MVC).

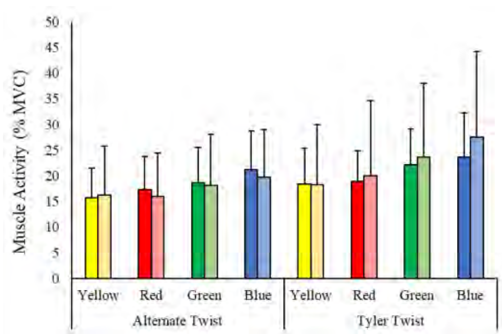

Figure 1: Average EDC muscle activity during each exercise. Colors refer to FlexBar resistance. Males (dark); females (light).

Discussion and Conclusions: Only EDC had a significant main effect for FlexBar resistance in both males and females. Therefore, when targeting the forearm extensors, the increase in resistance between FlexBars may not be large enough to elicit training progression. Greater changes in muscle activity were found in females across the FlexBar levels than males, which could be due to strength and/or anthropometric differences. Significant increases in forearm extensor activity when performing the Tyler Twist as compared to the alternating twist, for both males and females, may demonstrate a preferential training stimulus. Future work will consider grip and wrist strength to improve clinical decision making for optimal FlexBar selection.

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INVESTIGATING SITE-SPECIFIC CHANGES IN THE MECHANICAL PROPERTIES OF THE ANNULUS FIBROSUS FOLLOWING DISC HERNIATION

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Introduction: Disc herniations transpire when the nucleus pulposus within the intervertebral disc breaks through the surrounding annulus fibrosus [1]. Disc herniations have been demonstrated to be a result of cumulative damage brought on by repeated flexion under compressive stresses [2]. Limited research has investigated the mechanical consequence of disc herniaton to the annulus, however, it is not known if these changes are isolated to only the region of the herniaton or the entire annulus.

Aim: To investigate the site-specific changes in the mechanical properties of the annulus following disc herniation.

Methods: A total of 20 porcine cervical spines will be used (10 control, 10 experimental). The C3/4 and C5/6 functional spine units (FSUs) will be excised from these spines and randomized into groups via quasi randomization for each condition. The porcine segments will be loaded into an electromechanical materials testing system (MTS Systems Corporation, Eden Prairie, MN, USA) at a compressive load of 1400 N, with repetitive cycles of off-axis bending at 30° at 1 Hz to create herniation in the 10 experimental spines; figure 1. The control samples will be loaded at 1400 N but will not undergo repetitive flexion-extension. The reasoning for the off-axis herniation protocol is to force the herniation to one side of the posterolateral region of the annulus [3]; figure 1. This will yield a herniated region and an internal control region of the posterolateral annulus. Following loading, two annulus samples will be excised from each of the herniated and the intact regions. Similarly, from the control FSUs, two annulus samples will be excised from the left and right posterolateral region of the disc. A lamellar adhesion peel test will be conducted on one annulus sample and a single lamellae layer test will be conducted on the other sample using the UStretch (Cellscale, Waterloo, Ontario) and Biotester (Cellscale, Waterloo, Ontario), respectively. Mechanical properties will be quantified from both tests. A two-way ANOVA will be conducted to examine the main effect of condition (herniation/control) and posterolateral side, and the interaction between these two variables.

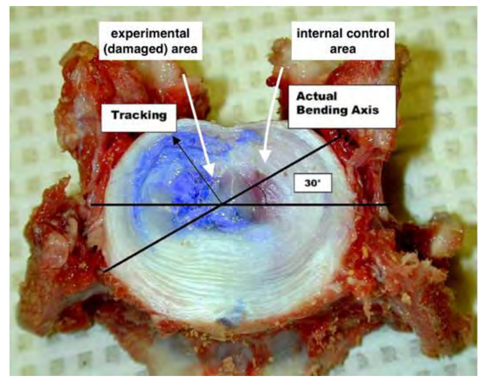

Figure 1: Sectioned C3/4 motion segment. Segment bent about the 30° axis (left to sagittal axis) [3]. Experimental area directly behind axis, internal control area to the right of experimental.

Expected Results: It is hypothesized that there will be differences in mechanical properties between the experimental group and control group, in that the control group will have greater annular strength than the experimental group. It is further hypothesized that there will be more site-specific damage in the region of the herniation directly behind the 30° axis compared to the intact region.

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UNDERSTANDING BALANCE CONTROL DURING GAIT PERTURBATIONS IN ADULT ATTENTION DEFICIT HYPERACTIVITY DISORDER

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Introduction: Attention Deficit Hyperactivity Disorder (ADHD) affects up to 10% of children and 5% of adults worldwide [1]. Studies investigating balance and sensory disruption found that ADHD adolescents have more issues balancing during disruption in comparison to control individuals [2]. There are very few studies looking at balance in adult ADHD. Among those that exist, one found that postural sway while standing on a tilt board was larger in ADHD individuals compared to controls and was associated with different cerebral grey matter volumes [3]. Another study found abnormally large body excursions and larger time delays between perturbation onset during stable standing and their response onset compared to controls [4]. Loss of balance through gait dysfunction is one of the most common reasons for falls, and can result in injury or death, yet there are no studies investigating balance control in adults with ADHD specifically during gait.
Aim: The aim of this study is to investigate whether ADHD individuals have balance control deficits in comparison to control individuals in responses to perturbations during the gait cycle.
Methods: Adults aged 17-35 years old with and without ADHD will be recruited. ADHD will be determined through a declaration of an official ADHD diagnosis. An Adult ADHD Self Report scale (ASRS) will be used to record ADHD symptoms and severity. Participants must be able to walk 30 m unassisted and have 20/20 corrected vision. The exclusion criteria will include musculoskeletal disorders or neurological disorders that affect balance including comorbidities with disorders like ASD or DCD. Participants will be asked to walk along a 10-m walkway during perturbed and unperturbed trials, which will be an unexpected uneven walking surface. The uneven walking surface will be induced with a flat board with either rigid (unperturbed trial) or complaint (perturbed trial) support. Stability during the walking trials will be determined by using the OptoTrak Motion Capture System (Northern Digital Inc., Waterloo, Ont., Canada) for information on center of mass (COM) and base of support (BOS), as well as force plate data (AMTI, Waterdown, MA) for calculation of center of pressure (COP).
Expected Results: It is expected that adult ADHD participants will have more issues recovering their balance after a perturbation during gait than control participants.

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EFFECTS OF PROLONGED STANDING IN OCCUPATIONAL FOOTWEAR ON BALANCE RECOVERY

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Introduction: Employees are required to wear standardized occupational footwear (OF), which are often bulky, heavy, and rigid, to reduce slips and injuries in the workplace. Research has shown that walking in OF requires greater muscle activity [1,2] but when an unexpected slip is encountered, less lower limb muscle activation and joint kinematic changes are needed to recover balance [2]. One limitation of these studies is that they were not collected under ecologically valid conditions since they did not consider how prolonged (>2 h) standing in OF might influence these results. This is important because workers often experience prolonged standing, which is associated with the development of lower limb and lower back discomfort (LBD) in the workplace [3].

Aims: The purpose of this study is to investigate how wearing OF affects gait and the ability to respond to an unexpected slip after a period of prolonged standing.

Methods: Thirty participants without any recent low back or lower extremity pain will complete two testing sessions separated by one week. They will wear their preferred athletic footwear (AF) in one session and a provided standardized OF for the other. In both sessions, participants will complete five normal walking trials by walking down an 8 m walkway at their preferred speed. Participants will then complete a two-hour standing protocol while performing common occupational tasks (e.g., typing, small assembly, etc.). After the standing protocol, participants will complete another three normal walking trials. For all eight normal walking trials, a high friction surface will be placed overtop the force plate located in the middle of the walkway. For the second session only, an extra walking trial will be collected following the last post-standing walking trial. This will involve replacing the high friction surface with a low friction surface without the participants knowledge to induce an unexpected slip. For both sessions, visual analog scale scores (VAS) will be used to quantify the level of pain experienced throughout the standing protocol, while surface electromyography will be recorded from lower limb and trunk muscles, ground reaction forces will be measured with a force plate, spine and lower limb joint kinematics will be measured with a motion capture system during the walking trials.

Expected Results: It is hypothesized that standing in OF will lead to higher VAS scores and affect fatigued walking behaviors, when compared to AF. Specifically, walking in OF post-standing trials will result in larger shear forces and smaller changes in lower limb joint angles. It is also hypothesized that these changes will result in a more severe slip outcome when encountering an unexpected slip in OF, requiring larger kinematic changes and muscular activation to recover balance.

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THE EFFECT OF EXTENDED REACH ON MANUAL ARM STRENGTH AND HAND LOCATION RELATIVE TO THE SHOULDER

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Introduction: Estimations of manual arm strength (MAS) are used in ergonomics analyses to compare manual force demands against the physical capacity of the population. The 'Arm Force Field Method' [1] was developed to accurately estimate acceptable manual force demands, requiring only the inputs of hand force direction, torso orientation and hand locations within the reach envelope. Despite performing very well within the defined task space, predictions of MAS are limited to a hand location no further than 80% of maximum reach for a 50th percentile female, complicating analyses when the arm is stretched beyond this limit.

Aim: This study will explore how MAS is affected when arm reach is extended to maximal (100% reach) and supra-maximal (>100% reach, via scapular rotation) distances, for a combination of several force directions and hand locations.

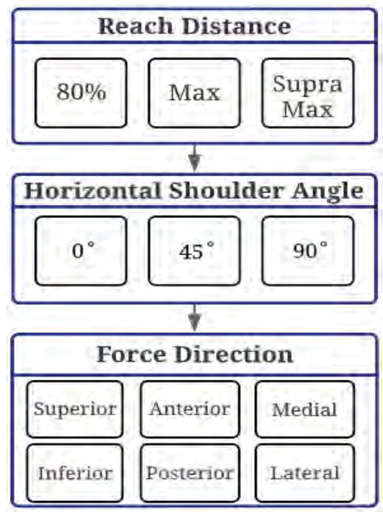

Figure 1. Experimental Conditions

Methods: 30 right-hand dominant female participants (aged 18-35), free from upper extremity pain or recent surgery, will be recruited. Reflective markers will be affixed to the participants' torso and upper extremity to track upper body kinematics, and an acromion cluster will be used to track scapular motion (Shaheen et al. 2011) using VICON Nexus 2.3 software (Vicon Motion Systems, Ltd, Oxford, UK). MAS will be collected using a Bertec PY6-500 force transducer (Bertec, Columbus, OH, USA) to measure maximum force in six directions of exertion (medial, lateral, inferior, superior, anterior, posterior), three reach distances (80%, maximal, supra-maximal), and three horizontal shoulder abduction angles (0°, 45°, 90°). 54 MAS exertions will be conducted in a randomized order with at least one-minute of rest provided between trials. A mixed effects model will be applied using dependent variables of MAS and reach distance, with fixed effects of exertion direction, reach distance, and horizontal shoulder abduction angle, and participant as the random effect.

Expected Results: We postulate that MAS will decrease for most force directions at the maximum and supra-maximal reach distances. Based on scapular motion, further reach distances are expected at 0° (i.e. shoulder flexion in the sagittal plane), which will translate into increased strength deficits. We anticipate that this research will provide recommendations for how to compensate for maximal reach scenarios when using the AFF in future ergonomics analyses.

References:

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WRIST KINEMATICS DETERMINED USING OPEN-SOURCE COMPUTER VISION BASED MARKERLESS MOTION CAPTURE: ANALYSIS OF A LOW-COST CAMERA SYSTEM

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Introduction: Motion capture systems are useful for quantifying kinematics in the laboratory, however, they are generally not useful in occupational settings. Typical methods of posture assessment in the workplace include live observation, video recording, or instrumentation such as an electrogoniometer. To allow for an accessible solution that can be deployed in a workplace, we propose a method to determine wrist kinematics for occupational applications using consumer-grade cameras and open-source software. The open-source software utilizes pre-defined convolutional neural networks that can be trained to predict anatomical landmark locations from video footage which can then be used to predict wrist angles.

Aim: To determine the accuracy of a low-cost multiple-camera system compared to a 12-camera optoelectronic motion capture system for quantification of wrist kinematics during workplace tasks.

Methods: Participants will perform three simulated workplace tasks (assembly, pick and place, and a typing task). Participants will be outfitted bilaterally with 7.9mm spherical VICON® (VICON, Oxford, United Kingdom) markers on metacarpals 2, 3 and 5, as well as the radial and ulnar styloid processes. Data will be acquired using 4 GoPro Hero 11 Black cameras (GoPro, San Mateo, California, United States) positioned at varying heights (Figure 1) arranged to provide right-side, frontal, overhead, and oblique views. Twelve VICON cameras (10 Bonita, 2 Vero) will simultaneously record marker motion at 120 frames per second (fps) while the GoPro cameras will record video footage at 120 fps. To quantify wrist kinematics (radial/ulnar and flexion/extension angles), video footage will be processed using the Anipose toolkit. The toolkit will approximate anatomical landmarks in a 3D coordinate system [1] that leverages the DeepLabCut machine learning toolbox [2, 3]. Flexion/extension and radial/ulnar deviation angles will be predicted from this 3D wrist model.

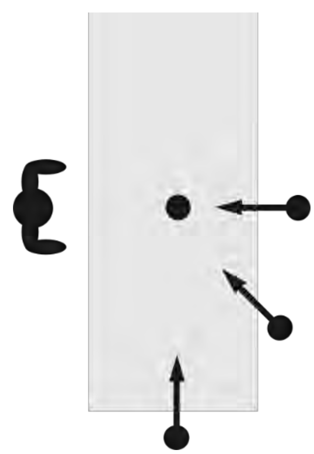

Figure 1: Overhead View of GoPro Camera Set-Up

Expected Results: A previous study using DeepLabCut in our lab on data obtained from a single overhead camera to predict radial-ulnar deviation angles achieved RMSEs of 2.75 and 7.03 degrees, for the right and left hands respectively [4]. We expect that using Anipose to triangulate multiple cameras coupled with the improved camera quality and increased training data over our previous work will increase angle prediction accuracy.

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AGE-RELATED CHANGES IN RELATIONSHIPS BETWEEN SPATIOTEMPORAL AND KINEMATIC DOMAINS DURING TREADMILL GAIT

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Introduction: Falls represent an ongoing and increasing public health problem in Canada, especially as our population continues to age [1]. Falls, and the age-related changes associated with them, correspond to major causes of morbidity and mortality in older adults [2-3]. That gait is a common activity preceding falls emphasizes the need to understand how gait changes throughout the aging process, and subsequently identify at-risk individuals [4]. Age-related changes to spatiotemporal (ST) parameters and joint kinematics during gait include reduced velocity and step length [5], increased stance width and double-support time [5], and decreased hip and ankle range of motion (ROM) [6]. Further, the nature of the relationships between these two domains is dependent on age [7]. Relating ST parameters and joint kinematics is essential to understanding biomechanical changes in gait [7] over the lifespan.

Aim: The aim of this study is to quantify age-related changes in relationships between ST parameters and joint kinematics during treadmill gait.

Methods: Participants consisted of 60 adults, evenly distributed between male and female, aged 20 to 80 years old (n=10 per decade). Participants were living independently, free of hip or knee replacements and impairments to balance or mobility, and comfortable walking on a treadmill. A passive motion capture system (Oqus 400+, Qualisys, IL, USA) tracked whole-body motion during approximately 10 minutes of treadmill walking (TMX425, Mortara, KS, USA) at two speeds: self-selected and slow (80% of self-selected speed). Joint kinematic (ankle, knee, hip, pelvis, and trunk ROM) and ST (step length, width, velocity, and time) measures were extracted for 50 steps from each speed. Linear mixed models will be used to quantify the relationships between the ST parameters and relevant kinematic measures [7] (e.g., step length and hip flexion-extension), and how these relationships change with age.

Expected Results: It is predicted that the relationship between joint kinematics and ST parameters will differ with age, such that the joint with the strongest associations to ST parameters will shift from the hip to the ankle with increasing age [7]. Further, we expect that these changes will be more pronounced in the slow speed. This study will provide insight into the relationship between these two biomechanical domains, and may lead to determining fall predictors in older adults. In turn, this may inform interventions to prevent falls, and for monitoring gait patterns [2]. This is essential to better support older adults, enabling them to maintain functional independence and quality of life.

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MEASURING PRESSURE ON THE HANDS AND ITS EFFECTS ON INTERNAL LOADING

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Introduction: The hands are essential in everyday life. Force has been identified as a risk factor to the development of these injuries [1] yet has not been adequately measured or represented. Pressure mapping systems show promise in providing multiple sites and magnitude of acting on the hands. This information can be used to calculate internal tissue loads using biomechanical models. Previous models have placed the point of force application at specific sites on the finger, either at the centre of mass of the distal phalanx, or at the fingertip [2]. The effect of complex loading profiles with several points of force application have yet to be. This more realistic representation of loading should change our views on joint and tissue loading as well as our understanding of injury mechanisms.

Aim: To use hand pressure mapping to determine points of force application and loading on the hand and to evaluate their effects internal tissue loading.

Methods: Twenty-six (26) right-handed participants (13 male and 13 female) of varying hand sizes will be recruited. The TekScan Grip system (TekScan, Boston, MA, USA) will be used to measure pressure and centre of pressure (CoP) on 17 regions of the hand. Upper extremity motion capture and force transducer data will also be collected. Participants will complete three maximum voluntary power grips (MVG). Then participants will complete 3 trials of the following static tasks held for 10 seconds, i) power grip at 20% MVG and 40% MVG (d =15 mm), ii) power grip at 20% MVG and 40% MVG (d = 25 mm), iii) single finger pressing task, iv) multiple fingers pressing task. The pressure will be used to compute the force distribution and the CoP will be used to determine the location of force application. These will be used as inputs into an OpenSim wrist and hand model to compute net joint moments, muscle activations and muscle forces. The location of the external loads will be changed to act at the CoP or at the centre of mass of the segment to mimic traditional assumptions. Statistical analyses will be used to determine the effects of exertion level and location of external load on model outputs. The effect of the number of fingers loaded will also be explored.

Expected Results: Model outputs for each condition will be reported. The results are expected to show differences of the model outputs due to the inherent variability in grasping. Examining the effect of multiple loading sites as an input to computational models of the hand will lead to better estimates of internal joint and tendon loads, thus improving understanding of injury mechanics. The knowledge of this study can be applied to existing biomechanical models of the upper extremity to provide a different representation of human-object interactions.

References:

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EXPLORING THE EFFECTS OF MENTAL FATIGUE ON PERCEPTUAL MOTOR TASK PERFORMANCE AND UPPER LIMB KINEMATICS

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Introduction: Despite the well documented evidence of the negative impact that mental fatigue (MF) has on endurance and strength-based performance, relatively little research has examined the impacts of MF on perceptual motor tasks[1]. This research has produced contradictory results, with many of these studies demonstrating a negative relationship, and others demonstrating no impact of MF[2,3]. As such, the purpose of this study was to examine the impact of MF on upper limb kinematics and performance accuracy in a novel perceptual motor task requiring aiming performance.

Methods: 40 participants were recruited for this study and were randomized either into an MF (n=20) or control (n=20) group. Dart throw accuracy and kinematic performance were observed as both groups performed two sets of 30 bullseye aimed dart throws separated by a 10-minute MF or control task. Shoulder (flexion/extension & adduction/abduction), elbow (flexion/extension), and wrist (flexion/extension & ulnar/radial deviation) joint angles at the start and end of the dart throwing motion were observed along with dart throw accuracy and dart throw timing.

Results: Averaged MF-VAS scores were 72.0% higher in the MF group relative to the control group ($p < 0.001$, $\eta_p^2 = 0.476$) suggesting the success of the MF task. No significant changes in accuracy performance or kinematic variables were associated with MF apart from a significant decrease in shoulder flexion at the end of dart throwing motions ($p = 0.013$, $\eta_p^2 = 0.152$), with MF group end of movement shoulder flexion angle decreasing from pre to post intervention by 2.2° and control group increasing by 0.8° over the same period.

Discussion and Conclusions: This study found very few relevant effects of MF on dart throwing accuracy and upper limb kinematics. One potential explanation for the lack of significant findings was the notable variability observed among all outcome measures, likely due to the complex unconstrained nature of this task, which may have resulted in the masking of any performance-related deficits due to MF (Figure 1). The results of this study indicate a need for future research to allow for a more nuanced understanding of the mechanisms through which MF impact perceptual motor tasks, perhaps through a more constrained task or through evaluation of a skilled population.

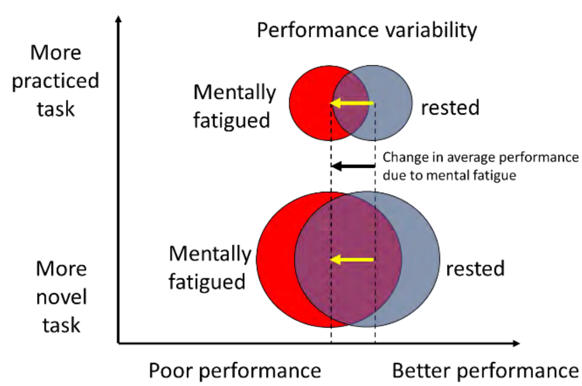

Figure 1: Conceptual diagram demonstrating the theoretical impact of performance variability and task practice on observable changes due to mental fatigue.

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EFFECTS OF AGE ON RELATIONSHIPS BETWEEN KINEMATICS AND CENTRE OF MASS MOTION IN THE FREQUENCY DOMAIN DURING GAIT

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Introduction: Globally, 30-40% of older adults experience a fall annually [1]. A strong link has been found between fall risk in older adults, and impairments in balance and gait patterns [2]. Relationships between kinematics and postural stability during gait have been examined in the time domain, with stronger relationships at the hip and ankle for younger and older adults, respectively [3]. Relationships between biomechanical signals (e.g., postural sway and free moment) during quiet standing have also been investigated in the frequency domain, where stronger relationships were found at lower frequencies [4]. However, there is a gap in the literature with respect to relating COM motion and joint kinematic signals in the frequency domain during gait. Gait is a functional task required daily for living independently. Thus, it is important to understand the biomechanical changes and relationships that occur throughout the gait cycle with aging.

Aim: The purposes of this study are: to quantify relationships between joint kinematics and COM motion during gait in the frequency domain; and to investigate the effects of age on these relationships across the frequency spectrum.

Methods: Sixty volunteers, aged 20-80 years old (n=10 per decade, evenly distributed between males and females), were recruited for this study. Participants were living independently, comfortable with treadmill walking, and free of hip or knee replacements and impairments to balance or mobility. Participants walked on a treadmill (TMX425, Mortara, KS, USA) while 3D full-body motion was tracked using passive motion capture (Oqus 400+, Qualisys, IL, USA). From the motion capture data, joint and segment kinematics (ankle, hip, and trunk) and extrapolated center of mass (XCOM) signals [5] will be calculated. Frequency analysis will be used to examine relationships between selected pairings of XCOM and angle signals in the corresponding direction (e.g., antero-posterior XCOM and flexion-extension joint angles) [3]. Specifically, phase shifts between the signals will be quantified using the difference between phase angles from Fast Fourier transforms; and relationship strengths will be quantified using signal coherence [6]. Phase shifts and signal coherence for each XCOM-angle pairing will then be compared between age groups and treadmill speeds.

Expected Results: It is hypothesized that the relationships between joint kinematics and COM motion will become weaker as age increases; and for all ages, stronger relationships will be seen at lower frequencies. Findings will improve our understanding of relationships between biomechanical signals throughout the gait cycle, which may aid in identifying mechanisms for gait dysfunction and falls risk in older adults.

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APPLICATION OF A SHORT TIME FOURIER TRANSFORM FOR GAIT BOUT DETECTION IN FREE-LIVING TRUNK WORN ACCELEROMETRY

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Introduction: Gait assessments provide valuable insight into fall risk, independence, and overall health and quality of life. Wearable devices enable gait to be measured in non-clinical environments, continuously for several days or weeks, revealing patterns of behavior and fluctuations in symptoms of disease. Gait detected at the lower back or ankle is common, however a device worn on the chest allows for accurate analysis of additional, important health-related biophysical signals (e.g., electrocardiography (ECG)). The primary objective of this study is to determine the accuracy of gait bout detection using accelerometry at the chest.

Methods: Participants (n=82, age=63.9 (29-87) years old, %female=81.7, height(cm)=155.7(30.8), weight(kg)=70.8(13.8)) wore Bittium Faros 360 device (Bittium Corp., Oslo, Finland) on the chest (ECG plus tri-axial accelerometer) and an Axivity AX6 IMU (Axivity Ltd, Newcastle, UK) above the ankle of the dominant limb, continuously for 7 days. A step detection algorithm applied to the ankle gyroscope data [1] and a step frequency threshold for bout definition was used as the reference dataset. We developed a custom gait bout detection algorithm employing a Short-Time Fourier Transform (STFT, 3-s window with 1.52s and 0.33 Hz resolution) for chest worn accelerometry. Gait bouts were defined by the first and last time bins of summed powers across 1-4 Hz frequency band [2] exceeding 0.06, while signal amplitude thresholding was applied to verify vertical upright posture and step occurrence [3]. Kendall tau correlations were used to evaluate the associations between algorithms for detecting medium (40-300 steps) and long (>300 steps) walking bouts. Gait bouts shorter than 40 steps were removed for this analysis.

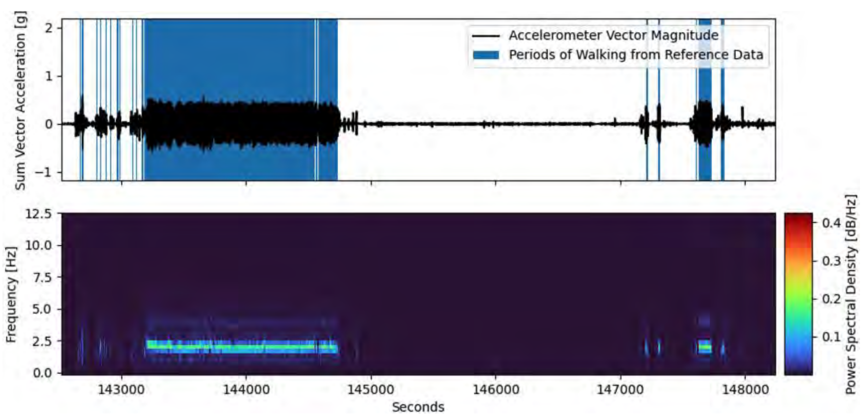

Figure 1. Frequency Analysis Plot; STFT: 3-Second, 1/3-Hz Resolution

Results: Average number of bouts from ankle method were 17.4 (range:0-118) long and 204.8 (26-790) medium bouts, respectively. The number of bouts detected by chest accelerometry were, on average, 21.6 (0-150) for long and 394.4 (22-1594) for medium bouts. Strong associations between the STFT algorithm and reference dataset existed for detecting walking medium and long bouts (tau=.51, p<.001) and Wilcoxon signed rank test revealed no difference between methods (W=592, p=.66).

Discussion & Conclusion: The STFT method to detect gait bouts has strong relative agreement with gait detected using an ankle IMU. Algorithm performance differences are likely due to two main factors: (1) differences in step and walking detection methods, clustering peaks into walking bouts compared to frequency domain methods and (2) parameters within the frequency domain analysis (e.g., resolution). Future work will continue to optimize frequency domain analysis and expand the utility of chest/trunk detected gait to include step detection accuracy and temporal measures of gait to indicate gait control strategies in free-living environments.

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EFFECTS OF GAIT VARIABILITY ON ADAPTATION TO ANKLE EXOSKELETONS

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Introduction: In the past decade many exoskeletons have reduced the energetic cost of walking [1]. However, acheiving these benefits often requires hours of walking time, during which the user must adapt to the complex novel dynamics created by the exoskeletons [2][3]. Recent work suggests that high gait variability may facilitate this adaptation by providing exposure to different-cost gaits [3][4]. Here, our purpose is to test how gait variabilty, whether naturally occuring (implicit) or created through encouraged exploration (explicit), effects the rate and magnitude of a users' adaptation to ankle exoskeletons. We hypothesize that individuals who display high implicit gait variability will more readily adapt to the device and that inciting explicit variability will expedite adaptation.

Methods: We will test 10 healthy adults with no prior experience walking in an exoskeleton. To date, we have tested 2 participants. We instrumented participants with bilateral ankle exoskeletons (Humotech, PA, USA), controlling the applied torques using a custom real-time angle-based controller. We also instrumented participants with lower-limb motion capture (Qualisys, Gothenburg, Sweden) and EMG (Delsys, MA, USA), and an indirect calorimetry system (Cosmed, Rome, Italy). All walking occurred on a fully instrumented treadmill (Bertec, OH, USA). During a baseline trial the exoskeletons were unpowered, allowing participant habituation and measurement of natural gait variability. Next, the exoskeletons were turned on and we assessed the level of adaptation both before and after an exploration trial where we incited high gait variability using verbal and visual prompts.

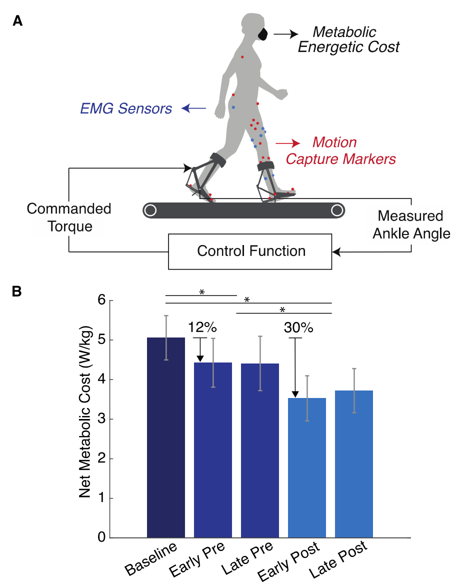

Figure 1: A) Participant instrumentation. B) Metabolic reductions before (Early and Late Pre) and after (Early and Late Post) the encouraged exploration trial for an

Results: Preliminary findings suggest that encouraged exploration may facilitate adaptation toward more energy optimal gaits. In one example participant, net metabolic cost reductions of 12% were achieved pre-exploration, but these savings more than doubled post-exploration to 30% (Figure 1B). Next steps include evaluating adaptation in soleus and gastrocnemius EMG, ankle range of motion, step frequency, and mechanical exoskeleton power, as well as evaluating the effects of implicit and explicit variability.

Conclusions: Our work will help elucidate the role of implicit and explicit gait variability during adaptation to lower limb exoskeletons. This may provide insight into how we can best facilitate and expedite the adaptation process when a user is learning to walk with a novel assistive device.

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THE ROLE OF LOW BACK CAPACITIES ON FUNCTIONAL MOVEMENTS

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Introduction: Heterogeneity in movement patterns is sometimes found within seemingly homogenous populations. For example, within a group of healthy firefighters randomly assigned to a six-month intervention of movement-focused exercise, differing changes in movement patterns during functional movements were found [1]. It is possible that different physical capacities related to movement may render certain interventions effective for some and not for others. It is reasonable to hypothesize that the overall combination of different physical capacity levels within each individual could be an important factor in explaining the heterogeneous performance in what were previously considered homogeneous samples.

Aim: The aim of this study is to elucidate how physical capacities of the low back (i.e., muscular strength, muscular endurance, motor control, and proprioception) may contribute to strategies in functional movements. Specifically, this study will investigate the effect of these capacities on lumbopelvic coordination, as well as hip and lumbar angle variability during a squat (SQT), lunge (LNG), and single leg Romanian deadlift (RDL).

Methods: Functional movement performance of 16 males and 16 females will be divided into phases using ground reaction forces collected from force plates (Advanced Mechanical Technology Inc., MA, USA), and movement strategies within these phases of motion will be quantified using a 3-dimensional motion capture system (Northern Digital Inc., ON, Canada). Next, proprioception will be quantified by the minimum error between actual and self-perceived halfway position in lumbar range of motion. Voluntary motor control will be quantified by a measure of motion smoothness during a repeated lumbar flexion/extension task. Reflexive motor control will be quantified using the electromyography latency of the lumbar erector spinae muscles in response to a quick-release trunk perturbation. Strength will be quantified by the maximum force output of an individual during an upright pull test [2]. Endurance will be quantified by the length of hold time in the upright pull test at 60% of the maximum pull force. Individuals will be grouped by lumbar capacity using a hierarchical clustering method. Lumbopelvic coupling angle and angle variability will be computed to compare functional movement strategy across clusters.

Expected Results: Individuals will form statistically significant clusters based on lumbar capacities. Clusters may form based on sex, however sub-clusters within each sex are also expected to form. Lumbopelvic coupling angle will be significantly different across clusters depending on movement (SQT, LNG, RDL) and phase of motion.

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HORIZONTAL VS. VERTICAL JUMPS IN RETURN-TO-SPORT TEST BATTERIES POST-ACL RECONSTRUCTION

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Introduction: Horizontal jump tests are one of the most commonly employed return to sport (RTS) assessments for ACLR patients[1]. However, recent studies have demonstrated persisting lower extremity biomechanical deficiencies in ACLR patients during vertical jump tests despite having been cleared to return to sport[2].

Aim: Therefore, the purpose of this study is to quantify and compare lower extremity muscle activation patterns of healthy controls during horizontal and vertical jump tasks.

Methods: 30 healthy participants between the age of 18 and 25 will be recruited for this study. Surface electromyography (sEMG) (Trigno™ wireless system; Delsys Inc. Natick MA) will be collected bilaterally (and normalized to each muscle's MVIC) from the biceps femoris, vastus medialis, vastus lateralis, rectus femoris, semimembranosus, semitendinosus and the medial and lateral heads of the gastrocnemius of healthy participants. Two AMTI force plates (BP600900; Advanced Mechanical Technology, Inc., Water-town, MA, USA) will collect ground reaction force, while lower extremity kinematics will be quantified using a 17 camera Qualysis motion capture system (Qualysis, Gotenborg, Sweden). In addition, knee flexor and extensor isometric muscle strength will be measured with a Biodex™ system (Biodex Medical Systems, Inc, Shirley, NY, USA). Data will be collected while participants perform three sets of two vertical (single- and double-leg vertical jumps), and three horizontal (single- and double-leg jumps, stop jumps and triple hop) jumping tasks. The peak EMG and the EMG timing will be extracted from the jumping and landing phases of each jump and compared across tasks. The correlation between muscle activation for each task type and muscle strength will also be quantified.

Expected Results: It is hypothesized that the vertical jump tasks will result in increased quadriceps and hamstring muscle activation compared to the horizontal jumps and that these will correlate better with quadriceps and hamstring strength compared to the horizontal jumps. Moreover, this study will result in improved RTS assessment selection that can better identify readiness to return to sport via biomechanical deficiencies that would otherwise be masked.

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ELECTROMYOGRAPHIC ANALYSES OF DYNAMIC FATIGUING CONTRACTIONS USING WAVELET AND COMPLEXITY METHODS

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Introduction: During isometric contractions, amplitude and Fourier transform-based spectral parameters of the surface electromyography (sEMG) signal are effective for monitoring fatigue-related changes in muscle electrical activity. However, these sEMG parameters are not robust to non-stationary signals during dynamic contractions [1]. Continuous wavelet transform (CWT) and sample entropy (SampEn) may be better suited for dynamic contractions because they can capture instantaneous frequency components [2] and quantify signal complexity [3], respectively. Thus, the purpose of this study was to assess the relationship between fatigue and CWT and SampEn during fatiguing trunk flexion-extension (FE) movements.

Methods: Twelve participants performed up to 12 sets (stopping with predefined criteria) of 50 repetitions of trunk FEs while wearing sEMG sensors and an inertial motion capture suit. Between sets, perceived fatigue and maximal lift strength were measured using a visual analog scale (VAS) and load cell, respectively. The major frequency components (MF) of the CWT and the modified SampEn (MSE) were calculated using bilateral lumbar erector spinae sEMG. The spine motion composite index (SMCI) was computed to quantify trunk movement variability, comprised of peak value of the thoraco-pelvic continuous relative phase signal, repetition time, and pelvis and T8 vertebrae orientation range, peak orientation, angular velocity, and angular acceleration [4].

Results: A linear mixed model showed that both MF and MSE significantly decreased throughout the fatiguing sets ($p \leq 0.004$). While neither sEMG parameters were correlated to maximal lift strength ($p \geq 0.051$), both were negatively correlated with fatigue VAS ($p \leq 0.005$) and SMCI ($p \leq 0.01$). On the individual-level, MF and MSE were significantly correlated with at least one variable (maximal lift strength, fatigue VAS, and/or SMCI) for 6 and 5 participants, respectively.

Discussion and Conclusions: Both MF and MSE mapped onto participants' perceived fatigue and changes in movement variability. While additional research is needed, these results suggest that MF and MSE of sEMG may be used to monitor fatigue during dynamic contractions. A challenge in developing kinematic-based fatigue monitoring systems is obtaining a ground truth of fatigue status that is measured concurrently with task performance; this study shows that MF and MSE of sEMG may be useful for this purpose.

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APPLICATION OF MULTISCALE ENTROPY FOR COMPLEX LOWER LIMB ACCELEROMETRY DURING CLINICAL WALKING TASKS

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Introduction: Clinical gait assessments can yield valuable outcomes to predict fall risk, assess motor-cognitive impairments, infer independence and overall quality of life. Accelerometry recorded using wearable sensors have gained traction as reliable and valid tools to analyze gait, with improved gait event detection at ankle worn locations [1]. Gait outcomes rely on accurately detected gait events, however algorithm performance across persons, diseases, and tasks, is inconsistent due to the complexity of accelerometer signals. Multiscale entropy (MSE) has been used previously to evaluate gait stability, by quantifying the complexity of acceleration time series data, using inertial measurement units worn at the waist without relying on gait event detection [2], however limited to no research has applied these techniques to sensors measuring lower limb movement during clinical walking tasks. Our work is specifically directed to a focus on those with motor and/or cognitive impairments that can impact gait and mobility where clinical gait assessments are particularly important.

Aim: The aim of this study is to determine whether gait performance measures such as temporal symmetry and step to step variability are associated with multiscale entropy (MSE) outcomes when analyzing lower limb acceleration data.

Methods: 50 persons living with cerebrovascular disease were recruited as part of a longitudinal cohort study and selected as a convenience sample for a secondary analysis. Participants wore tri-axial accelerometers (Gulf Coasts Data Concepts, Waveland, USA) bilaterally above the ankle while completing 7 different walking trials: three preferred walking (PREF), two arithmetic dual tasks (DS1, DS7), one verbal fluency task (DAN), and one fast walking trial (FAST) over an 8 m walkway (including 1 meter acceleration buffers). Raw data was sampled at ~100 Hz and down sampled to 40Hz for analysis. Gait events were detected using a peak detection algorithm that relies on signal magnitude and timing thresholds analyzed using a custom LabVIEW program (National Instruments Corp, USA). Multiscale entropy measures will be implemented using python programming language.

Expected Results: Entropy analytics applied to ankle worn accelerometry is limited, however MSE has high concurrent validity and reliability to infer gait stability using waist worn inertial measurement units [3]. It is hypothesized that entropy measures will change as task difficulty increases (dual task or fast walking) with larger differences in those presenting asymmetry or increase gait variability. These analytical techniques may overcome barriers experienced by complex accelerometer waveforms that increase the error in gait event detection due to walking that is complicated by high step to step variability, contains transient interruptions or very slow walking. These challenges can occur during dual task walking and among individuals with impaired control that can lead to very slow and/or shuffling gait. Further analysis will investigate the impact of including gait acceleration within MSE analytics due to the complex nature of defining steady state and acceleration periods of gait in clinic and free-living environments [4].

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OPTIMIZATION OF MUSCLE ACTIVATION SCHEMES IN A FINITE ELEMENT NECK MODEL SIMULATING VOLUNTEER LATERAL IMPACT SCENARIOS

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Introduction: The activation of neck muscles is crucial in determining the head and neck response during an impact, and it can influence the likelihood of injury [1]. However, the effect of muscle activation level and timing in lateral impact injuries still requires further investigation. Finite elements (FE) Human Body Models (HBMs) can estimate the response of the head and neck to impact, which is a piece of vital information for safety systems. Still, verified and validated strategies for neck muscle activation are lacking. This study aimed to improve comprehension of neck muscle activation by finding optimized schemes for lateral impact scenarios using a HBM.

Methods: The head-and-neck model was extracted from an average-stature male HBM (M50-O v4.5, GHBMC) for left-to-right lateral impact simulations. The optimization method presented in previous work [2] was used to optimize the muscle activation timing (ms) and level (0 to 1) in four muscle groups (right extensors (RE), right flexors (RF), left extensors (LE) and left flexors (LF)) for four lateral impact scenarios (4-7g). The simulations were assessed using volunteer experiments from the literature [3]. The T1 kinematics of the experiments were applied to the model T1 and the head kinematics were compared to the output of the HBM. The optimized muscle activation (OMA) response was compared to the response of the cocontraction muscle activation (CMA), no muscle activation (NMA) and maximum muscle activation (MMA) schemes from the literature [2]. The simulations were conducted using commercial FE software (LS-DYNA R.7.1.2, Ansys, PA, USA) and the responses were compared using correlation analysis described in previous work [2].

Results: The OMA schemes consistently improved the kinematic response for all impact cases (Figure 1). As the impact severity increased, the OMA onset times decreased for the extensors and right flexors and increased for the left flexors.

Impact severity (g)	4	5	6	7
RE level	0.10	0.08	0.05	0.02
RF level	0.98	0.99	0.99	1.00
LE level	0.11	0.12	0.13	0.14
LF level	0.05	0.20	0.34	0.48
RE onset (ms)	64.38	61.45	58.52	55.59
RF onset (ms)	55.76	55.51	55.25	55.00
LE onset (ms)	63.19	60.65	58.11	55.57
LF onset (ms)	94.40	95.82	97.23	98.65

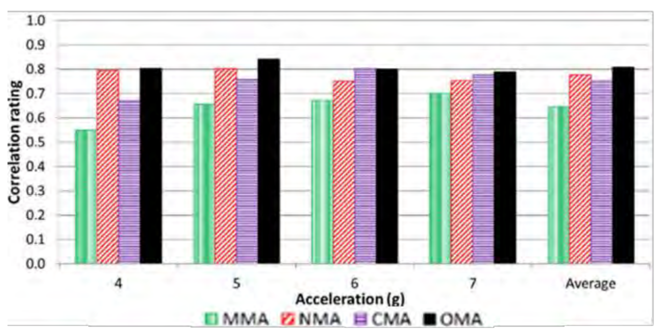

Figure 1: a) OMA activation level and onset time, and b) correlation to the experimental data.

Discussion and Conclusions: The onset times for the optimized right extensors and flexors agreed with experiments from the literature [4]. Neck movement in lateral impacts is complex and future analysis increasing the discretization of the muscles in more than four groups may improve the response of the model. In conclusion, the OMA improved the neck response and will enhance HBM to better inform head and neck injury risk and prevention methods during impact.

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The Effect of Hand Load Stability on the Recruitment of Shoulder Stabilizing Musculature during Bench Press and Military Press Variations

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Introduction: The shoulder complex provides large mobility at the cost of stability. Muscles must accomplish tasks while maintaining joint integrity, in particular the humeral head within the glenoid fossa. The supraspinatus and infraspinatus stabilize the humerus, mitigating excess superior and anterior translations [1][2]. Current literature lacks description of posterior rotator cuff recruitment during common near-maximal pushing exercises such as free weight bench press and military press. Further, characterization of the glenohumeral stabilizers' responses to different manual demand conditions can improve definition of their mechanical roles.

Aim: To investigate the activation patterns of shoulder stabilizing musculature during common push exercises with varying manual control requirements.

Methods: 20 healthy young adults (10 M, 10 F) with 6 months or more training experience and free of shoulder injuries will participate over two sessions. The first session will confirm eligibility, familiarize participants with the equipment and exercise form, and estimate their one repetition maximum (1RM) of both bench press and military press, as outlined by the American College of Sports Medicine [3]. At least 48 hours later, participants will perform 4 reps per trial at 85% of their estimated 1RM in all combinations of exercises (bench press vs military press) and conditions (free weight vs pulley and coupled vs uncoupled hand forces). These 8 trials will be presented in a quasi-randomized order. 3-D kinematics will be collected using a 13 camera Vicon MX20 motion capture system (Vicon, Oxford, UK) with markers placed over the chest, arms, and exercise equipment. Surface electromyography (sEMG) will be unilaterally collected for supraspinatus, infraspinatus, anterior deltoid, middle deltoid, long head of triceps brachii, clavicular and sternal heads of pectoralis major, long head of biceps brachii, latissimus dorsi, upper trapezius, and serratus anterior via a wireless 16-channel Noraxon TeleMyo 4200T G2 (Noraxon 2 USA Inc., Arizona, USA). EMG data will be normalized and quantified during five exercise phases. Motion capture will define the five lift sections and quantify the linearity and tremor of the bar path. For each exercise, a three-way mixed ANOVA will examine main and 2-way interaction effects. Tukey posthoc tests will be used to identify differences in levels where significance is detected.

Expected Results: We hypothesize that conditions with decoupled hands will require more shoulder stabilizer contributions and increase tremor within the movement path. Overall, insight into the varied mechanical contributions of the muscles will also emerge, potentially yielding insights into more specific and effective exercise prescription.

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EFFECT OF ROTARY-WING AIRCREW HEAD-SUPPORTED MASS IN FLEXION POSITION ON THE TISSUE-LEVEL RESPONSE OF THE NECK: A FINITE ELEMENT STUDY

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Introduction: Rotary-wing aircrew (RWA) have reported the occurrence neck pain, potentially associated with rapid scanning tasks and head-supported mass (HSM) [1]. From the literature, increased muscle activity and increased forces in the spinal column can be potential causal pathways for neck pain [2]. However, additional insight is required to understand the interactions of HSM and non-neutral neck positions with the innervated tissues in the neck. Detailed finite element (FE) neck models (NMs) can provide valuable insight by assessing tissue-level stresses and strains and providing guidance on factors that may contribute to neck pain risk.

Methods: The ligamentous cervical spine comprising the C1-T1 vertebrae, skull (4.4 kg) and neck muscles (Hill-type) were extracted from the Global Human Body Model Consortium (GHBMC) M50 v5.1 human model [3]. The T1 vertebra and the inferior nodes of the muscle elements were constrained. A 25º head-neck flexion, with and without the HSM, was simulated by activating the muscles in the FE NM. The HSM (2.7 kgs) comprised helmet, night vision goggles and counterweight. The compressive force in the discs, annulus fibrosus (AF) strains and vertebral endplate stresses were assessed.

Results: Achieving the 25º forward flexion required higher levels of muscle activity for the HSM, compared to the case with no HSM. The resulting maximum spine compressive force, occurring at the C7-T1 level, was 245 N without the HSM, and 344 N with the HSM. Compressive force on the disc increased by an average of 47% across all cervical levels due to HSM. The maximum AF strain was 13.3% and 17%, without and with the HSM, respectively, at the C7-T1 level. The maximum AF strain increased with HSM by an average of 17% across all the levels from C2-C3 to C7-T1. The maximum effective stress in the vertebral endplates increased from 5 MPa to 11 MPa with the addition of HSM. Stress in the endplate increased with HSM by an average of 46% across all cervical levels.

Discussion: Increase in muscle activity required for the HSM led to an increase in disc compression force, endplate stress, and AF strains. Specifically, the increase in compression coupled with the forward flexed position of the neck led to increased AF strains at the endplate junctions. Increases in strains within the AF and stresses within the endplates have been associated with a higher risk of disc degeneration and will be investigated in future studies.

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COMPARISON OF DOMINANT VS. NON-DOMINANT LOWER EXTREMITY KINEMATICS IN RESPONSE TO AN ANAEROBIC-AEROBIC FATIGUE PROTOCOL

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Introduction: The majority of anterior cruciate ligament (ACL) injuries are non-contact in nature with females more likely to sustain an injury in their non-dominant leg compared to males [1]. One potential cause of this is neuromuscular fatigue that results in abnormal lower extremity kinematics subsequently leading to increased strain on the ACL. However, limited research has focused on quantifying kinematics between legs and sexes in response to localized neuromuscular fatigue.

Methods: Twenty healthy participants (10 males, 10 females) will be recruited and exposed to an aerobic-anaerobic fatigue protocol: sets of five squat jumps and 20 s of high knees until fatigued. Bilateral surface electromyography (sEMG) will be collected using wearable sensors (Trigno™ wireless system; Delsys Inc. Natick MA; interelectrode distance is 2.5 cm) on 8 lower extremity muscles, and the mean power frequency (MnPF) of the EMG signal will be monitored in real-time; decreases in the MnPF have been correlated with the onset of fatigue. Two AMTI force plates (BP600900; Advanced Mechanical Technology, Inc., Water-town, MA, USA) will measure ground reaction forces and three-dimensional kinematics will be quantified with an eight camera (Sony RX0 II; Sony Group Corporation, Tokyo, Japan) markerless motion tracking system that will be processed by Theia3D software (Theia Markerless Inc., Kingston, ON, Canada). Time to volitional fatigue and objective fatigue (10% decrease in MnPF) will also be measured. A mixed repeated measures ANOVA will be conducted to determine if there are differences in the knee joint kinematics between legs (dominant vs. non-dominant) and sex.

Hypothesis: Based on current research, it is hypothesized that the non-dominant leg in females will become fatigued faster compared to their dominant leg but that in males, the dominant leg will become fatigued first. This will result in kinematic alterations that are associated with an increased risk of ACL injuries.

Discussion and Conclusions: By comparing the fatigue related kinematic changes between the dominant and non-dominant leg and between sexes, this research will provide information leading to the development of methods and targeted programs to reduce the onset of neuromuscular fatigue in the lower extremity musculature and consequently reduce the risk of non-contact ACL injuries.

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SPATIAL CONTEXT OF VISUAL INFORMATION: INFLUENCE ON PERFORMANCE OF A WALKING TURN

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Introduction: To effectively locomote through the environment, humans must incorporate visual information from the world around them. Despite being an everyday occurrence, this is a challenging task: the central nervous system must determine and execute appropriate motor actions to adapt ongoing locomotion, maintain postural stability and progress toward the intended goal. Past research has determined that visual cues play a significant role in movement success. For example, a visual cue placed in the same visual field as the required motor response facilitates faster response times for relatively simple, upper limb movements versus when cues are contralateral to the required motor response [1]. Recently, we explored how visual spatial cue context affects a lower limb task: execution of a step when initiating gait with the left or right limb. We observed significantly greater anticipatory postural adjustment errors in the mediolateral plane when a step was cued by a visual stimulus placed contralateral to the stepping limb [2]. Similar postural errors were observed in a similar step onset protocol when attentional resources were redirected to a secondary button press task [3], suggesting that these errors may be linked to attentional processing. It is not fully understood if this effect is present during more complex motor tasks, such as ongoing locomotion.

Aim: To explore how individuals incorporate visual information of varying, irrelevant spatial location to change travel direction.

Methods: At least 20 young adults (age range 18-35 yrs) will be recruited to take part in this protocol. Participants will be asked to complete 70 walking trials. Two strides after initiating gait, participants will be presented with a visual cue in the form of either a left or rightward arrow projected on the wall in front of them (see Figure 1). Participants will be instructed to turn in the direction the arrow indicates (change in direction of approx. 60°) and come to a full stop two strides after completing the turn. Kinetic (AMTI; 100 Hz) and whole-body kinematic measures will be captured (Optitrack, NaturalPoint, inc. USA; 100 Hz) to assess the effect of these visual cue conditions on anticipatory locomotor adjustments, turn onset timing, spatiotemporal measures of gait (i.e., center of mass velocity, step length, width) and axial segmental control (i.e., head, trunk rotation onset and rotation magnitude).

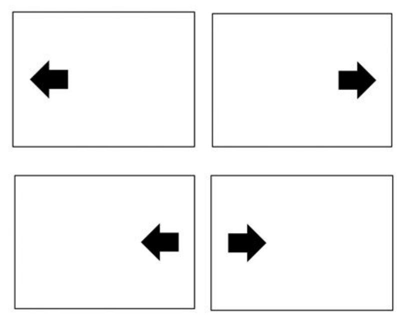

Figure 1. Visual cue placement; cue position is either ipsilateral (top row) or contralateral (bottom row) to turn direction.

Expected Results: We expect to observe longer turn onset times, and less stable turning behaviors when there is an incongruency between the spatial location of a visual cue and the direction in which an individual is required to turn. This work will add to our foundational knowledge of the relationship between visual integration and ongoing locomotion.

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Multi-camera video analysis of head impacts in youth hockey

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Introduction: Concussion research has become increasingly relevant over the last decade, as the reported concussions in Canada have surpassed 200,000 per year [1]. Concussion incidence rates in hockey are of particular interest, as they are nearly double those in other contact sports, such as football/rugby, cycling and skiing/snowboarding [2]. Research has shown that concussions in youth athletes tend to be more severe and more detrimental compared to adults. Instrumented equipment such as helmets have been utilized widely to collect collision-related data in sport [3]. However, relatively inexpensive multi-camera systems offer versatility while also enabling the descriptive analysis of head impact mechanisms, the analysis of player anticipation prior to impact [4], and the analysis of 3D head kinematics before and after impacts that occur during game play (e.g., in youth football: [5]).

Aim: This study aims to describe the mechanisms of in-game head impacts in youth ice hockey, the degree of anticipation of players prior to being impacted, and the head kinematics of impact cases using a multi-camera video analysis approach.

Methods: Seven GoPro Hero9 cameras (2.7K resolution, 4:3 aspect ratio, modified lenses with 47 degree fixed field of view to eliminate lens distortion) on adjustable and portable mounts will be placed around one hockey rink in the Windsor/Essex region, such that every area on the ice surface will be captured within the field of view of at least two cameras. Frame rate and shutter speed for the cameras will be determined during pilot testing in the rink environment. Video data will be collected during games for a U15 league for an entire hockey season. Calibration objects will be placed around the ice surface prior to the start of each game to enable 3D analysis (e.g., using ProAnalyst 3D). Every head impact over the season will be described from the events viewed on the video recordings. Degree of anticipation prior to a collision from another player will be assessed using the CHECC list [4].

Expected Results: It is expected that the data obtained in this study will provide new information on how head impacts are occurring and how anticipating impacts can affect head kinematics (and hence concussion risk) in youth ice hockey. The ultimate goal is to extend this work into a longitudinal study and, in conjunction with other data collection approaches, improve training and concussion prevention strategies for youth hockey players.

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THE IMPACT OF HIGH INTENSITY INTERVAL TRAINING VS MODERATE INTENSITY CONTINUOUS TRAINING IN PARKINSON'S DISEASE

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Introduction: Parkinson's Disease (PD) is a neurodegenerative disease characterized by various motor and non-motor symptoms including bradykinesia, rigidity, tremor, postural stability, and sleep disturbances [1]. Aerobic exercise has been shown to improve some of these symptoms [2], however research examining different exercise intensity in participants with PD is limited. This study compared the effects of moderate intensity continuous training (MICT) and high intensity interval training (HIIT) on maximal oxygen uptake (VO_2max), posture and gait in individuals with PD. We hypothesized that HIIT may be more advantageous over MICT due to health benefits observed in other populations after completing HIIT programs [3,4].

Methods: A total of 28 individuals (45 to 85 years; 11 F) with PD and no history of stroke, dementia, type 1 diabetes, or autonomic neuropathy were recruited to complete a 10-week supervised exercise program, attending 3 cycling classes per week. At baseline, 5 walking trials were performed to assess gait (GAITRite; 50Hz or Opal sensors, APDM Wearable Technologies Inc.; 128Hz). Postural stability was evaluated via 3 one-minute quiet standing trials (AMTI force plate; 50Hz). The Mini-BESTest clinical mobility test and anthropometric measurements were completed, and a cycling VO_2max test was performed. For each training session, the HIIT group completed 10, 1-minute intervals at 90% peak power alternated with 1 minute at 10% peak power; the MICT group cycled at 60% peak power, increasing gradually from 30 to 50 minutes. Following the intervention (97% compliance), baseline assessments were repeated.

Results: Both forms of training increased relative VO_2max ($p<0.001$) but did not result in statistically significant changes from baseline ($p>0.05$) for the Mini-BESTest. ANCOVA analyses controlling for baseline values also revealed no significant differences in any gait metrics (e.g., speed, %double support, cadence, stride length; all $p>0.42$).

Discussion and Conclusions: No statistically significant declines were observed in the gait measures calculated or the Mini-BESTest scores, which may be considered a positive outcome for a neurodegenerative population. The effects of training on gait and balance varied among participants, as some participants improved, and others did not. This may be explained by our sample of individuals with PD who experience variable disease and symptom severity. Postural stability data (e.g., center of pressure max/min; root mean square, etc.) is currently being analyzed.

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THE INFLUENCE OF SWIM BENCH ROTATION SETTINGS ON UPPER BODY KINEMATICS AND MUSCLE ACTIVITY PATTERNS IN SIMULATED SWIMMING

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Introduction: The swim bench is an isokinetic ergometer designed for competitive swimming training. Its intended purpose is simulation of the underwater pull during swimming; however, limited literature addresses the biomechanical fidelity of the swim bench relative to in-water swimming. Further, the lack of body roll on the swim bench may limit the fidelity of simulated freestyle stroke pulling. Accordingly, the Kayak Pro SwimFast swim bench includes a rotating bench setting. Yet, specific changes to a competitive swimmer's kinematics and muscle activation patterns with a rotating bench setting are unknown.

Aim: To guide swim bench use in training and research, this study aims to assess the influence of bench settings on kinematics and muscle recruitment while also comparing swim bench 3D kinematics to analogous pre-existing in-water kinematic data [1].

Methods: Fifteen, male, OUA/USport or national level competitive swimmers participated. Upper limb and torso kinematics were collected bilaterally using Vicon MX20 cameras (Vicon, Oxford, UK) at a sample rate of 150 Hz. Twelve right shoulder and arm muscles, serratus anterior, upper and lower trapezius, supraspinatus, infraspinatus, anterior, middle and posterior deltoid, pectoralis major (clavicular and abdominal regions), latissimus dorsi, triceps brachii, and biceps brachii were collected using Ag/AgCl surface electrodes and a wireless Noraxon Telemyo 2400R T2 system (Noraxon USA Inc., Arizona, USA) sampling at 1500 Hz. Two, 5 second maximum voluntary contractions were collected per muscle for normalization. Participants completed 8 block randomized sets (4 rotating, 4 fixed) of 30 seconds continuous pulling, 15 seconds active recovery, and 2 minutes passive rest on a KayakPro SwimFast swim bench (KayakPro USA LLC, Florida, USA). The time-series electromyography of the 2 settings will be compared to each other while the kinematics will be compared between settings and versus the pre-existing in-water data using statistical parametric mapping.

Expected Results: Freestyle stroke pull kinematics on the swim bench are expected to differ from the in-water data; however, the rotating swim bench setting is anticipated to more closely replicate the in-water freestyle pull than the fixed . Between bench settings, the rotating setting is expected to produce greater trunk rotation angles, shoulder joint angles ranges, overall stroke length, and maximum stroke while the elbow joint angle ranges and stroke width will be smaller . All 12 muscles are expected to have a greater peak amplitude and activate earlier on the rotating bench setting. This study will add to the sparse literature regarding the efficacy of the swim bench and will inform coaches and researchers of its utility as a sport-specific tool.

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THE IMPACT OF CYCLIC TENSILE LOADING AND IL-1β STIMULATION ON BOVINE CAUDAL ANNULUS FIBROSUS PROPERTIES

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Introduction: Intervertebral discs (IVDs) contain an outer annulus fibrosus (AF) – many concentric collagenous lamellae adhered together by an interlamellar matrix (ILM). The strength of adhesion between and across lamellae provides structure to the AF in its containment of the nucleus pulposus. Damage to the AF decreases the overall ability of IVDs to tolerate loading and increases the risk of IVD herniation. The combination of IL-1β inflammatory culturing and cyclic tensile strain (CTS) acted synergistically to reduce ILM adhesion by 40% where 1 ng/mL concentrations of IL-1β, or CTS alone were insufficient to alter adhesion [1]. Human AF cells exposed to 10 ng/mL IL-1β showed no difference in inflammatory biomarkers with and without CTS [2] showing that a degenerative phenotype can be induced by an inflammatory stimulus alone. However, this study did not evaluate the mechanical properties, but rather cell responses.

Aim: Examine the biomechanical and biochemical properties of IL-1β stimulation and CTS on bovine caudal AF samples.

Methods: C2-3 to C6-7 bovine caudal functional spinal units (FSUs) will be dissected into AF rings and cultured at 37ºC, 8.5% CO_2, and 6% O_2 for 7 days (Figure 1) with and without 10ng/mL IL-1β stimulation and CTS utilizing a MechanoCulture system (CellScale Biomaterials Testing, Canada). AF rings will be mounted on posts and subjected to cyclic displacement (2-3mm) for 3 h/day, for 5 days at rate of 1 Hz. Tensile loading data will be collected and windowed throughout the culturing process and analyzed alongside inflammatory marker PGE_2 at media collection timepoints. On day 7, AF tissues will be removed from the media and dissected for bilayer AF tensile testing (Figure 2A), 180˚ peel testing (ILM adhesion, Figure 2B), and cell viability analysis.

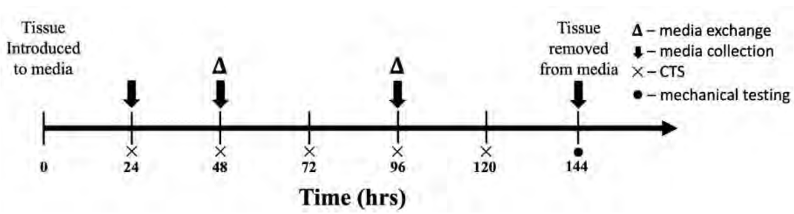

Figure 1: Timeline.

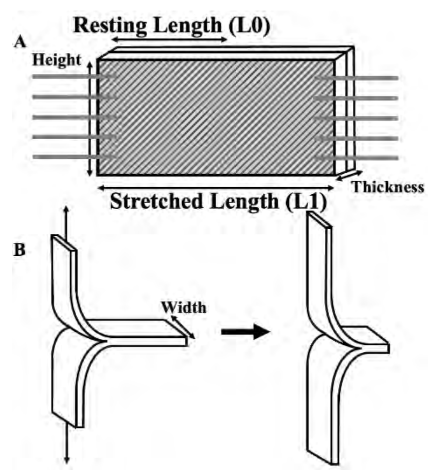

Figure 2: Bilayer (A) and peel test (B).

Expected Results: IL-1β culturing is expected to decrease peel strength and act synergistically with CTS to alter AF peel and bilayer properties. Changes in biomarkers are expected to precede changes in AF mechanical properties.

HOW LUMBAR SPINE POSITIONING AFFECTS CLINICAL DIAGNOSIS OF OSTEOPOROSIS AND DUAL-ENERGY X-RAY ABSORPTIOMETRY MEASURES

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Introduction: Osteoporosis-related fractures occur frequently in the lumbar spine, making it an important location to measure bone mineral density (BMD) and fracture risk using Dual Energy X-ray Absorptiometry (DXA) scans. As these can be repeated annually to track progression, variability in posture of the patient's spine between scans (often due to back pain) could affect clinical decision-making. Previous studies have investigated this effect but with large motions, such as 0°-60° axial rotations in 5-10° increments [1]. However, no studies have been conducted at smaller out-of-position angles, which may not be noticed by a technician. The goal of this study was to examine how small motions in each independent axis of the lumbar spine affect three clinical DXA measures: BMD, BMC (bone mineral content) and total area.

Methods: Four porcine lumbar spine specimens (T12-L5) were dissected to the vertebral column and spinal ligaments. The end vertebrae were secured in blocks of dental cement and mounted in a custom-made jig for DXA scanning (Hologic, Inc., Marlborough, MA, USA). A container of 15 cm deep water represented the x-ray attenuation of the removed soft tissues. A scan was taken in neutral posture, then again while five motions were applied to each specimen independently in 3° increments: extension, flexion, lateral bending, twisting, and axial rotation (random order). DXA measures of BMD, BMC and area were compared using a one-way repeated measures ANOVA (α=0.05) with post-hoc Fisher's Least Significant Difference (LSD) test.

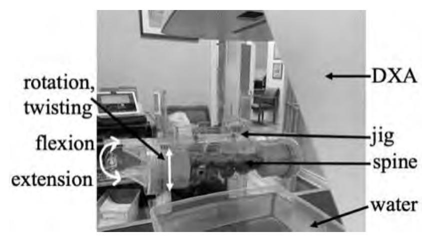

Figure 1: Experimental set-up.

Results: Lateral bending had a significant overall impact on BMD, BMC, and total area ($p<0.001$; $p=0.023$; $p=0.003$; respectively). Pairwise comparisons for BMD showed significant differences from neutral for 6°, 9°, and 12° extension ($p=0.012$; $p=0.029$; $p=0.050$; respectively), and 9°, 12° and 15° axial rotation ($p=0.010$; $p=0.013$; $p=0.010$; respectively). Neither BMC nor area was found to significantly differ from neutral for any posture tested.

Discussions and Conclusion: DXA is an important clinical tool as it guides treatment decisions. However, patient positioning may change with pain, with small variations difficult for a technician to identify visually. Lateral bend was found to have the largest impact on all DXA measures and should thus be the focus of patient positioning. Furthermore, patient placement guidelines should focus on angles larger than 6°, as these may affect BMD measures. The outcomes from this study are a first step towards producing guidelines for patient placement for reliable scanning over time.

References:

BIOMECHANICAL OUTCOMES OF SURGICAL VS NON-SURGICAL TREATMENTS FOR FEMORAL-ACETABULAR IMPINGEMENT SYNDROME IN FEMALE ATHLETES

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Introduction: Femoroacetabular impingement syndrome (FAIS) is a clinical hip disorder characterized by abnormal articulation of the femur and acetabulum due to bone overgrowth [1]. FAIS is treated surgically and/or non-surgically. It is more prevalent in athletes and females demonstrate a significantly greater incidence than males, as well as poorer hip-related function and quality of life [2]. Despite this, past research on FAIS frequently underrepresents females which may account for the poorer treatment outcomes shown in this population.

Aim: To quantify the biomechanical outcomes of surgical and non-surgical treatments for FAIS in female athletes.

Methods: Five patient-reported outcome measures (PROMs) will be collected remotely from 33 active females (age=18-40 years) who are healthy (n=11) or have undergone surgical (n=11) or non-surgical (n=11) treatment for FAIS. Using Kinovea®, lower extremity kinematics will be quantified from participant submitted videos of four body-weight squats and lateral lunges. One-way repeated measures ANOVAs will be used to compare PROMs, maximum squat depth, and peak joint angles between the three groups. A multivariate linear regression will be used to determine the relationship between demographics, PROMs, maximum squat depth, and joint angles. A preliminary analysis of four healthy and two surgical subjects has been completed.

Expected Results: Preliminary results show minimal between-group differences in maximum hip flexion (Figure 1) and minimum knee flexion (Figure 2) angles. Surgical patients show greater minimum hip flexion, less maximum knee flexion, and greater variability in these variables. Surgical patients move through less hip range of motion during the initial squat phase (Figure 3). These findings are expected to be amplified in non-surgical patients and to correlate to poorer PROMs among all FAIS patients relative to controls.

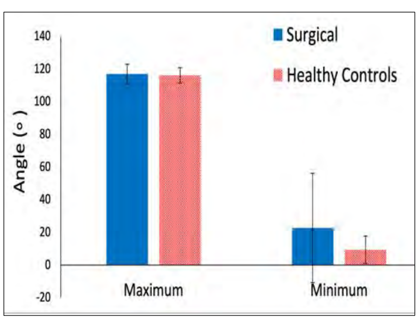

Figure 1: Maximum and Minimum Mean Hip Flexion Angles

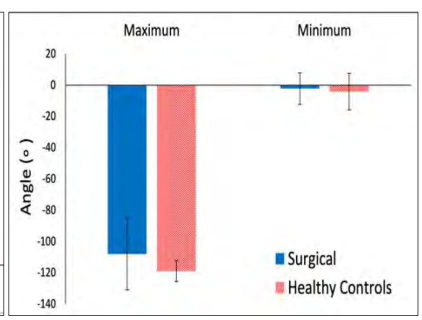

Figure 2: Maximum and Minimum Mean Knee Flexion Angles

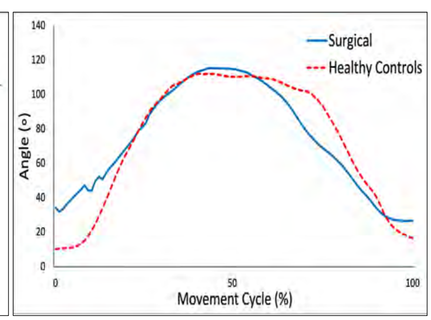

Figure 3: Time Series for Mean Hip Flexion Angle During Squat

PATIENT MEASUREMENTS FOR SUBJECT-SPECIFIC ACTIVE CONTROL OF A STROKE REHABILITATION ROBOT

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Introduction: During stroke patient rehabilitation, therapists currently don't have objective measures of the subject's motor control unless sensors/markers are physically placed on the subject's body, which can often present discomfort. A new stream of research focuses on the symbiosis between the patient and robot; subject-specific active control of robots evaluates the user's voluntary motion, from which robotic assistance is then tailored based on the user's ability or performance [1].

Methods: The end-effector-based robot used in this study is an actuated 2 degree of freedom (DOF) 4-linkage planar parallelogram manipulator. To measure the user's ability, a dynamic model of their upper arm (Figure 1) as a planar 2-DOF linkage was used to estimate the user's shoulder and elbow joint torques, using real-time kinematic data. To obtain this real-time kinematic data without physically placing sensors/markers on the user, a system of two equations (which defined the user's planar arm model in terms of their shoulder and elbow joint angles) was solved in real-time, assuming the user's shoulder joint centre didn't move in the horizontal plane. This joint angle estimation method was experimentally validated against the gold standard of a digital goniometer on a healthy subject, and compared against pre-trained pose estimation models. To further measure the user's performance, the robot was equipped with a force sensor on the end-effector, which was then used to implement a force direction-based control approach.

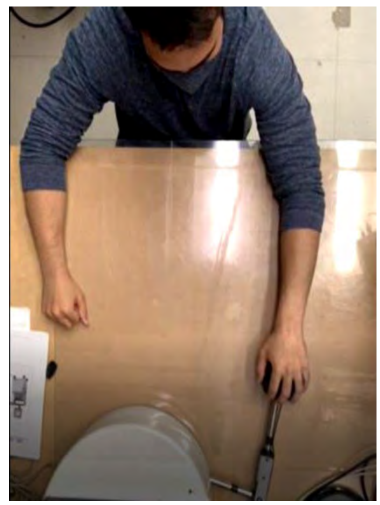

Figure 1: User using Rehab robot.

Results: The equation solver achieved a root mean squared error (RMSE) of 0.66 degrees with respect to 10 goniometer measurements, and an RMSE of 0.84 degrees with respect to a pre-trained computer vision pose estimation model [2] used on the same 10 pose instances. Experiments are currently being conducted on post-stroke patients to evaluate the effectiveness of this measurement system.

Discussion and Conclusions: This rehab robot not only helps to promote human engagement, but it also provides a means of measuring motor control recovery because it indicates the degree to which the patient is improving by the level of assistance needed from the robot.

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INVESTIGATING PORTABLE INSTRUMENTATION TO PROFILE KINEMATICS AND PLANTAR PRESSURE DURING ON-ICE STARTS IN LONG TRACK SPEED SKATERS

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Introduction: Technical analysis of long track speed skating skills in a real-world competitive environment is challenging due to a lack of portable and wireless instrumentation that does not interfere with the athlete's performance. The purpose of the study was to investigate the efficacy and compatibility of using portable instrumentation to profile skating mechanics, including kinematic and plantar pressure data during on-ice racing starts in elite level long track speed skaters.

Methods: Long track speed skaters (n = 4 males; >18 yrs) competing at an elite level were recruited. Participants completed a standard dryland warm up and were instrumented with kinematic and plantar pressure measuring devices. Kinematic data were collected using 17 wireless inertial sensors (Awinda, Xsens Technologies B.V., Netherlands) to determine joint angles (deg) of the hip, knee, and ankle joints. Plantar pressure data were collected using a wireless plantar pressure insole system (X4 Foot and Gait Measurement System, XSENSOR® Technology Corporation, AB, Canada) to determine mean plantar pressure [MP (psi)], peak plantar pressure [PP (psi)], push time (s), and cumulative centre of pressure (CoP) path length [PL (mm)]. The two systems collected data simultaneously during the execution of multiple on-ice racing starts. Participants were encouraged to perform at race intensity with adequate rest between starts. Kinematic and plantar pressure data were exported into MATLAB and time-synchronized. An on-ice racing start was defined as the initial push-off (stride 1), and the following five strides (strides 2-6) including both a recovery and push-off phase. Kinematic data were extracted from the final frame of the push-off phase of each stride; plantar pressure data were extracted throughout the push-off phase of each stride. Data from stride 1 were analyzed independently. Data from strides 2-6 were analyzed by side (R/L) and averaged per start. All participants initiated the starts with right foot dominance.

Results: Mean descriptive statistics for kinematic and plantar pressure data per stride are illustrated in Tables 1 and 2. Paired sample T-tests conducted on the right side revealed significantly greater knee and ankle flexion during stride 1, potentially contributing to the greater mean plantar pressure in comparison to strides 2-6 ($p<0.05$). Paired sample T-tests conducted on the right versus left leg joint angles across strides 2-6 revealed significantly greater knee flexion on the right leg ($p<0.05$).

Discussion and Conclusions: On-ice racing starts are a critical component of competition. Data-driven metrics obtained from portable and wireless instrumentation during the execution of on-ice racing starts provide athletes and coaches with technical details to refine performance.

Table 1: Descriptive kinematics (mean ± SD) during long track speed skating starts

	Stride Number	Hip Angle (deg)	Knee Angle (deg)	Ankle Angle (deg)
Right	1	38.3 ± 27.4	32.0 ± 12.2	10.7± 6.6
	2-6	28.6± 8.8	18.9 ± 8.8	-1.8 ± 5.3
Left	2-6	19.2 ± 6.6	16.4 ± 9.8	-1.9 ± 8.7

Table 2: Descriptive plantar pressure (mean ± SD) measures during long track speed skating starts

	Stride Number	MP (psi)	PP (psi)	Push Time (s)	PL (mm)
Right	1	7.64 ± 2.64	11.02 ± 3.04	0.68 ± 0.16	100.05 ±13.3
	2-6	6.71 ± 1.72	10.96 ± 2.48	0.67 ± 0.11	90.22 ± 16.5
Left	2-6	6.52 ± 0.95	11.11 ± 2.17	0.66 ± 0.09	101.31 ± 15.56

VALIDATION OF PHYSICAL ACTIVITY LEVELS FROM SHANK-PLACED AXIVITY AX6 ACCELEROMETERS

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Introduction: Physical activity (PA) for the aging population has been identified as a protective factor for various musculoskeletal disorders [1]. With the advent of wearable inertial sensors, researchers can obtain objective measures of PA from sensors at the wrist, waist, or thigh, compared to self-reported PA data which is subject to bias. Wearable inertial sensors are also widely used in gait research to collect free-living gait data, to study the progression of musculoskeletal diseases, such as knee osteoarthritis, which affects nearly 20% of Canadians [2]. In gait research, the placement of a sensor on the shank (i.e., below the knee) can provide meaningful data on the movement of the lower limb [3]. While this sensor placement is ideal to determine accelerations experienced by the knee, there are limited methods in place to determine PA from sensors worn at this location. Thus, in cases where accelerometers are only placed on the shank or near the knee, researchers must resort to using additional sensors placed in common wear locations to measure PA as well. This increases costs of research, is troublesome to participants wearing these sensors, and is ineffective, since this data can potentially be acquired from a single sensor.

Aim: Therefore, this study aims to investigate the convergent validity of outcomes derived from the ActiGraph GT9X and a shank placed Axivity AX6.

Methods: 40 participants over the age of 55 will enroll in this cross-sectional study. Each participant will wear one ActiGraph GT9X (ActiGraph LLC, FL, United States) on the waist and one Axivity AX6 accelerometer (Axivity Ltd., Newcastle, United Kingdom) below the right knee for a consecutive 72 hours, to collect free-living PA data. Cut-points for determining intensity levels (e.g., time spent in sedentary, low, moderate, and vigorous activity) from the shank-placed sensor will be determined through an optimization algorithm developed on a subset of participants (e.g., 10 adults) using gold standard data (e.g., ActiGraph results). These cut-points will then be used to determine the validity of the new shank-placed model on the remaining, withheld participants (e.g., 30 adults).

Expected Results: It is expected that cut points will be optimized at greater values given the sensors on the shank will experience greater impacts at the same activity levels. However, following this optimization, we expect excellent agreement with Intraclass Correlations Coefficients >0.9 for all intensity bins.

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BIOMECHANICAL CONSIDERATIONS RELATED TO EARLY SPECIALIZATION: HIP KINEMATICS IN ICE HOCKEY GOALTENDERS

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Introduction: Ice hockey goaltenders are at an increased risk of hip and groin injuries due to their highly specialized movement patterns, at end range hip flexion, adduction, and internal rotation (FAdIR). According to a prospective cohort study, in a single season 69% of goalkeepers experienced a hip and groin injury, however 15% led to time loss despite 36% being deemed a substantial injury[1]. This suggests that many goalkeepers are playing through pain and dysfunction. Additionally, over the last thirty years there has been an increasing popularization of athletes early specializing to achieve elite status, in which a synonymous increase in sport-specific injuries has been apparent[2]. It is thought that sport specialized (S) hockey athletes are at an increased risk of injury, which is enhanced in goaltenders due to the frequency of abnormal movement patterns. No study, however, currently exists quantifying hip kinematics in ice hockey goalkeepers and perceived hip pain and function or has analyzed potential differences across S and non-specialized (NS) goaltenders.

Aim: i) quantify hip kinematics in response to common goaltending and sport-specific movements, and compare between S and NS goaltenders; and ii) determine how kinematics correlate with patient-reported outcome measures (PROMs).

Methods: Current goaltenders (16-25 years) will be recruited and divided into two groups, specialized (n=15) and non-specialized (n=15). A previously developed questionnaire will be used to determine specialization status based on hockey participation before grade 9 of high school and training greater than eight months of the year[3]. An online survey using Research Electronic Data Capture (REDCap; Vanderbilt University, Nashville TN, USA) will be used to evaluate participants' hip function, pain, physical activity levels, and quality of life using five PROMs. Participants will then perform three trials of five goaltending specific and two sport-specific tasks. An eight-camera markerless motion tracking system (Theia Markerless Inc., Kingston, ON, Canada), will be used to quantify 3D lower extremity joint kinematics. Video data will be processed using Theia3D software (Theia Markerless, Kingston, ON). Hip kinematics and PROMs will be compared between groups using independent t-tests.

Expected Results: To date, data has been collected on 3 participants. I expect that the specialized group will demonstrate increased high risk hip motions (ie., FAdIR) during the goaltender specific tasks, compared to the non-specialized group due to poorer physical literacy. In addition, I expect that the specialized group will report increased pain and decreased function. I also expect that the S group will demonstrate higher injury risk kinematics during the generic tasks compared to the NS due to decreased exposure to non-goaltender specific movements.

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COMPARING CERVICAL AND LUMBAR SPINE ANGLES BETWEEN TABLET AND COMPUTER TASKS COMPLETED IN SITTING AND STANDING

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Introduction: Ergonomic guidelines tend to make recommendations with the goal of reducing the risk of pain or injury to the neck and low back postures during computer tasks. However, with increased tablet usage in the workplace, evidence-driven recommendations for tablet devices remain necessary. Cervical and lumbar spine angles have been evaluated for tablet use in sitting [1] and hybrid postures [2], but comparisons between sitting and standing have not been made. Given differences in spine postures and pain responses between sitting and standing, cervical and lumbar spine kinematics during tablet work should be assessed in both seated and standing work.

Aim: To examine differences in cervical and lumbar spine flexion-extension angles when performing simulated office tasks on a tablet and computer in both sitting and standing.

Methods: Twelve participants (7F/5M) will complete a series of five-minute tasks which include typing, reading, and data entry on both a computer and tablet device. The tasks will be completed in both sitting and standing. Task order will be block-randomized by posture. Participants will be instrumented with passive reflective markers that will be tracked by VICON MX20 infrared cameras. Marker clusters will be adhered to the thorax at approximately the eighth thoracic vertebra (T8), the sacrum of the pelvis, and individual markers will be adhered to the ears and at the seventh cervical vertebra (C7). Following dual pass filtering with a second order low pass Butterworth filter with a cut-off frequency of 3 Hz, mean cervical and lumbar flexion-extension angles in each trial will be calculated (Visual 3D, C-Motion Inc., MA, USA). The angles will be expressed relative to the angle observed in an upright standing calibration trial. Three-way mixed analyses of variance ($\alpha = 0.05$) will be performed to compare between task device (tablet and computer), posture (sit and stand), and sex (male or female). Post hoc pairwise comparisons will be performed using a Bonferroni correction.

Expected Results: It is expected that both cervical and lumbar spine flexion will be greater in sitting than standing postures [3]. Additionally, based on findings that individuals position tablet devices differently than a computer monitor (i.e., held closer to facilitate typing, often propped against the work surface) [1,2], it is expected that using the tablet device will elicit greater cervical and lumbar spine flexion than when using the computer in both sitting and standing.

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A NOVEL COMPLIANT SUPPORT MECHANISM FOR CERVICAL ARTIFICIAL DISC REPLACEMENT

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Introduction: Artificial disc replacement (ADR) is an alternative to anterior cervical discectomy and fusion (ACDF) spinal surgery, typically performed on patients to retain greater spinal mobility and reduce risk of adjacent segment disease. However, ADR has clinically reported reoperation rates ranging up to 20% [1, 2]. In addition, other concerns exist around ADR implants in relation to the implant wear producing foreign particles in the body, and existing ADR implants' lack of biomimetic mechanical properties.

Aim: The goal of this work was to develop a novel mechanical design for ADR to address concerns with existing designs related to implant wear, lack of biomimetic mechanical properties, and provide a method for greater customizability of ADR implants.

Figure 1: A 2-Pronged Compliant Support Mechanism for ADR

Methods: Implant designs were made with Solidworks (Dassault Systèmes, France) to have a compliance profile resembling the cervical intervertebral disc. Multiple designs were then computationally tested via Abaqus FEA (Dassault Systèmes, France), and the most promising designs were additively manufactured in Ti64 through Laser Powder Bed Fusion on the EOS M290 printer. Initial mechanical characteristic measurements were taken with an AMTI VIVO™ (AMTI, USA) under 5 cycles of simulated axial compression (80N), flexion (2Nm), and torsion loading (1Nm). Axial stiffness and range of motion (ROM) in flexion and torsion were calculated post-hoc.

Results & Discussion: The 2-pronged design showed greater range of motion in both flexion and torsion than the 3-pronged design. The 3-pronged design showed higher axial stiffness in compression. Pilot data collected for one sample of each design type is shown in Table 1. Additional testing is planned to fully characterize the compliance profile of each compliant support mechanism design. Compared to previous reported values of intervertebral disc mechanical properties, these initial results indicate promising biomimetic efficacy of the design [3].

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Table 1: R.O.M. and Axial Stiffness data for 2- and 3- pronged compliant flexure designs

Design Type	Axial Stiffness (N/mm)	Flexion R.O.M. (deg)	Torsion R.O.M. (deg)
2-Pronged	171	4.5	1.8
3-Pronged	210	3.1	1.6

VALIDATION OF A SINGLE CAMERA-BASED HUMAN MOTION CAPTURE SOFTWARE (TUMEKE) FOR ERGONOMICS RISK ASSESSMENTS

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Introduction: Advancements in deep learning have improved the accuracy of pose estimation from markerless motion capture [1]. Mathematical algorithms can now be used to extract behavioural measurements and body configurations non-invasively from 2D videos captured by a single smartphone [2]. Human factors/ergonomics professionals are interested in this technology for its ability to measure body postures and movements in the workplace, since these two parameters can be used to assess work-related musculoskeletal disorder risks [3]. Therefore, it is crucial to understand the validity of this technology for in-field ergonomics assessments.

Aim: To compare the outputs from a single camera-based human motion capture software (TuMeke) to that from a criterion inertial measurement unit (IMU) system in a meat processing environment.

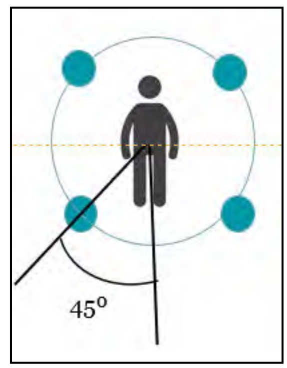

Figure 1: camera setup

Methods: 20-30 participants will complete meat processing tasks on the production floor of a meat processing plant. Participants' upper extremity kinematics will be collected by both an upper extremity IMU-based-system (Life Booster Senz) and 2D digital video from 4 off-axis views (Arlo Pro2) simultaneously (Figure 1). The recorded videos will subsequently be analyzed using the TuMeke software. The standard outputs from each system will be compared.

Expected Results: Due to the inherent differences in IMU and video-based pose estimation, the continuous time series outputs are hypothesized to differ between the two technologies. The information provided by this analysis will inform ergonomists using the TuMeke product which camera views yield the most accurate results for ergonomics analysis.

References:

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INVESTIGATING THE EFFICACY OF A NOVEL COUNTER MEASURE TO REDUCE MUSCLE ACTIVITY WHEN DONNING NIGHT VISION GOGGLES

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Introduction: Neck injury and pain has been a long-time issue for Canadian Armed Forces rotary wing pilots when wearing night vision goggles. The added mass and associated flexor moment induced by the night vision goggles increases cervical spine loads and requires increased muscle activity from neck extensor muscles for pilots. Currently, adding a counterweight to the back of the helmet is the chosen solution for reducing neck moments and muscle activity when individuals are maintaining static upright neutral head and neck postures. However, when considering dynamic tasks, the addition of a counterweight also increases the moment of inertia of the helmet, leading to higher peak neck muscle activation to initiate and stop head motions. Thus, a novel intervention which considers the dynamic requirements of the aircrew is needed to address night vision goggle associated neck trouble.

Aim: This study aims to assess the efficacy of a novel lateral-sliding counterweight designed to reduce biomechanical exposures during dynamic simulated aircrew visual acquisition tasks.

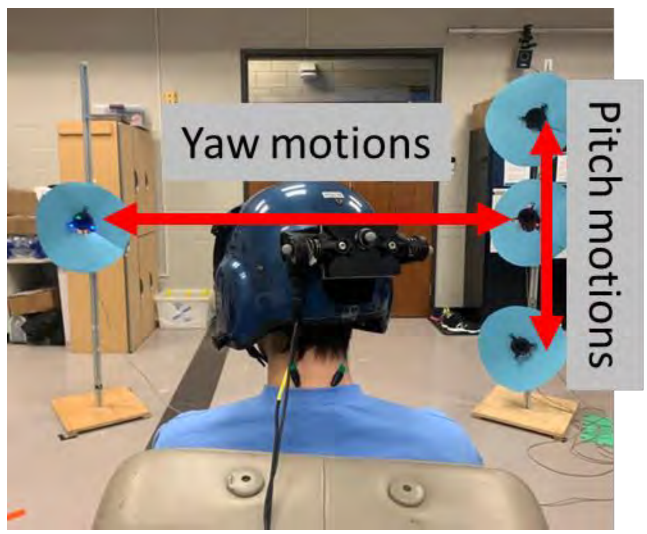

Figure 1: Lab set up of equipment in horizontal direction.

Methods: 30 participants will perform a rapid reciprocal aiming tasks while wearing a fitted rotary wing pilot helmet under 5 different conditions: 1. control (no attachments), 2. night vision goggles only, 3. counterweight, and the novel lateral sliding counterweight (4. low spring stiffness and 5. high spring stiffness). With a helmet mounted laser pointer, subjects will move their head to cycle between a pair of solar panel sensors mounted in the vertical (pitch) and horizontal (yaw) directions (Figure 1). Solar sensor target acquisition performance will be measured by calculating the total number of successful target acquisitions within the 20s protocol. Electromyography (EMG) will be measured bilaterally from the sternocleidomastoids, splenius capitis, and upper trapezius to evaluate changes in peak and mean muscle excitation between conditions.

Expected Results: We hypothesize that the laterally moving counterweight conditions will result in an increase in the number of acquired targets and a reduction in peak and mean EMG in all muscles relative to the traditionally used counterweight when rotating in the yaw direction. In contrast, we expect to see no differences between the laterally moving counterweight conditions and the traditional counterweight when rotating in the pitch direction. Results from this study may play an important role in determining the efficacy of a novel lateral-sliding counterweight to reduce aircrew neck troubles.

EXPLORING THE RELATIONSHIP BETWEEN SLEEP AND PHYSICAL ACTIVITY IN PRESCHOOL-AGED CHILDREN OVER THE COURSE OF A YEAR

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Introduction: Physical activity (PA) and sleep are important, modifiable behaviours that play a critical role in the healthy growth and development of children [1]. However, according to Statistics Canada, only 15% of Canadian preschool-aged children follow the recommended PA and sedentary time guidelines [2] and obtain the suggested amount of sleep [3]. While there seems to be a general understanding that the duration of PA, particularly in moderate-to-vigorous PA (MVPA), is positively related to sleep outcomes in adults, the evidence is less clear in preschoolers [1]. With the rising trend in sedentary behaviours and decreasing trends in MVPA, it is necessary to investigate the bi-directional related nature of PA and sleep in preschoolers to not only determine how these behaviours impact the overall health of an individual, but to also determine how they impact one another, especially in the growing years [1].

Aim: (1) To determine how sleep and PA trajectories of preschool aged (1.5-5 years) children in the Guelph Family Health Study (GFHS) may change over a year, and **(2)** explore the associations between different PA measures (sedentary, light PA, MVPA, total PA) and different sleep measures (total sleep time, sleep efficiency, wake after sleep onset) over the course of a year.

Methods: Baseline, 6-month, and 1-year data of preschool-aged children collected by the GFHS will be utilized in these analyses. The GFHS is a longitudinal study that assesses the success of health promotion interventions in families. PA and sleep were measured using a tri-axial accelerometer (100 Hz, ActiGraph™, wGT3X-BT, Pensacola, Florida, USA). Participants were instructed to wear the monitor on their right hip for 7 days, except for activities involving water. Raw data were downloaded using the ActiLife program (version 6.13.1) and exported to 1 sec (PA) and 60 sec (sleep) epochs. PA data and will be further processed by removing periods of non-wear and age-appropriate cut points will be applied. Sleep data will be cross validated using logbooks and algorithms will be applied to detect sleep/wake and calculate sleep metrics. Parental education and household income will be controlled (Repeated measures ANOVA).

Expected Results: PA and sleep analyses are currently ongoing. It is expected that preschoolers who engage in greater PA intensity (i.e., more minutes per day in MVPA) may also experience better quality (i.e., fewer wake times) and a higher quantity of sleep (i.e., greater total hours of sleep). It is also expected that sleep and PA trajectories will decline for preschoolers as they age.

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DEVELOPMENT OF LOWER EXTREMITY NEUROMUSCULAR MAPS TO OPTIMIZE RETURN-TO-ACTIVITY DECISIONS FOLLOWING MUSCULOSKELETAL INJURY

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Introduction: Lower extremity musculoskeletal injuries are common among soccer players. Kicking is a common, and distinctive aspect of a soccer athlete's activity and injuries have been shown to occur during this set of motions. However, a thorough understanding of muscle activation patterns and appropriate coordination of the lower extremity is missing.

Aim: The aim of this study is to quantify muscle activation patterns of the lower extremity and abdominal muscles during a maximal in-step kicking tasks.

Methods: 40 healthy, competitive soccer athletes will be recruited for this study. Surface electromyography (EMG), collected bilaterally from eight lower extremity and trunk muscles (normalized to each participant's maximal voluntary isometric contraction (MVIC)) and three-dimensional kinematics will be quantified in response to three maximal in-step kicks. For analysis, five phases of the kick will be identified: i) preparation; ii) back swing; 3) leg cocking; iv) acceleration; and v) follow-through

Expected Results: Expected results include minimal rectus abdominus (RA) activation during the preparation phase despite the occurrence of trunk flexion. I also expect minimal RA during the leg cocking phase despite max hip extension occurring. The greatest semitendinosus, semimembranosus and biceps femoris activation in both supporting and kicking leg occur during the cocking phase. The RA, rectus femoris, vastus lateralis, vastus medialis, and adductor longus will be maximally activated during acceleration and follow-through. These expected findings suggest that certain lower extremity muscle groups are exposed to greater demands during certain phases and that the supporting and kicking limbs are activated differently. An improved definition of lower extremity function during kicking will provide a basis for improved insight into injury risk reduction and rehabilitation. Future research will investigate how differences in neuromuscular activation between healthy and injured participants may relate to differences in the risk of lower extremity injury among soccer athletes.

ROBOTIC REHABILITATION AS A TOOL TO PROMOTE UPPER LIMB CROSS-EDUCATION IN MULTIPLE SCLEROSIS

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Introduction: Cross-education (CE) is a neurophysiological phenomenon whereby one limb is trained, and the opposing limb also demonstrates improvements. To elicit CE in either strength or motor control, it is necessary to perform numerous repetitions under tension or force [1]. One way to safely execute this for individuals with minimal function is with the use of robotic devices. Robotic end-effectors offer gravity assistance, external resistance, and postural grooving through efficient and anatomically correct positions, all of which are facets of optimal rehabilitation. CE can be an effective rehabilitation tool whereby training the less affected limb leads to improvements in the otherwise immobile limb. To date, the exact neurophysiological mechanisms involved in CE remain scarcely explored in populations with impaired neurological function.

Aim: To use an adaptive robotic training program to induce the neurophysiological effects of cross-education in healthy participants and individuals with multiple sclerosis.

Methods: 30 participants diagnosed with multiple sclerosis (MS) and 20 healthy controls will participate. Participants will place their forearm on a robotic device (Figure 1, Wristbot, Genoa, Italy) and perform an eccentric contraction exercise (wrist reaching) against robotic resistance 3 times weekly for 8 weeks. Participants will train their less affected limb and changes in the untrained limb will be evaluated. Surface electromyography (EMG) will be placed over the flexor capri radials and extensor carpi radialis. Using a butterfly coil (MagStim, UK) transcranial magnetic stimulation (TMS) will be used to stimulate the contralateral motor cortex. TMS measures of peak-to-peak motor evoked potentials (MEPs) amplitude, silent period, active motor threshold, and recruitment curves will be recorded to assess corticospinal excitability pre/post/follow-up training. H-reflexes will be elicited for FCR by stimulating the median nerve (DS7A; Digitimer) and peak-to-peak amplitudes recorded.

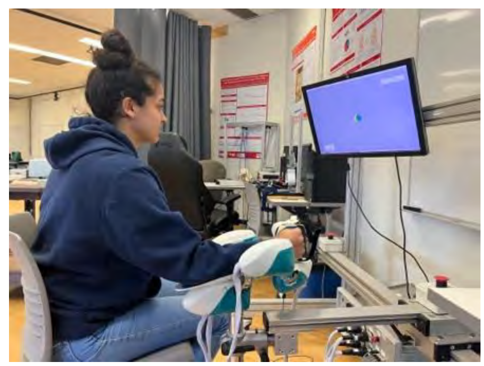

Figure 1. Participant using Wristbot, facing monitor with visual feedback.

Expected Results: Following the 8 weeks of robotic rehabilitation, it is hypothesized that increases in corticospinal and spinal excitability will occur following the training program as recorded via TMS eliciting larger MEP amplitudes in both forearm muscles. Participants are expected to show significant improvements in the trained and untrained limbs. CE has been highly researched in healthy populations and spinal cord injury, yet there is minimal evidence for individuals with MS. Thus, this work will contribute greatly to upper extremity MS rehabilitation research such that optimal robotic training protocols can be developed.

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MECHANICAL AND HISTOLOGICAL TESTING OF MOUSE SPINES TO EXAMINE INTERVERTEBRAL DISC DEGENERATION ASSOCIATED WITH MENOPAUSE

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Introduction: Post-menopausal women experience a greater prevalence of IVD degeneration compared to pre-menopausal women and men of the same age [1]. Previous mouse-based studies of IVD degeneration have used ovariectomies to create a model of menopause. However, while this significantly reduces estrogen production, it reduces testosterone production as well, and creates an abrupt, non-physiological change in these hormones. An alternative model uses 4-Vinylcyclohexane Diepoxide (VCD) injections to promote a more gradual early onset menopause while maintaining testosterone production [2]. The current study investigates the effects of VCD and perimenopause on the mechanical and histological properties of IVDs in mice. It is hypothesized that those treated with VCD will show lower spinal stiffness compared to those in the control group. In addition, histological analysis of the VCD group will show a lower IVD height and greater degeneration compared to that of the control group. Last, physical training (i.e. treadmill running) will mitigate these differences in trained compared to sedentary VCD groups.

Methods: 30 sexually mature female CD-1 mice were divided into three groups across two time points: control-sedentary, VCD-sedentary, and VCD-training. The VCD groups were injected with 160 mg/kg daily for 15 days following a week of acclimation. The sedentary groups did not undergo any physical exercise while the VCD-training groups were exposed to two or eight weeks of treadmill training. Sacrifice occurred on day 134 (T1, n=5/group) and day 176 (T2, n=6/group) post-injections to create two timepoints. Following sacrifice, the lumbar spines were removed and underwent cyclic compression-tension mechanical testing to determine neutral-zone (NZ) stiffness and length. Histological analysis has yet to occur.

Results: For NZ stiffness, the only between group difference occurred at the T2 timepoint, where the VCD-training group was significantly less stiff than the control-sedentary group. Interestingly, an overall decrease in stiffness was found in all three groups between T1 and T2. No statistically significant differences were found in NZ length between groups or timepoints.

Discussion and Conclusions: It was expected that spine stiffness would decrease in the VCD mice as they progressed post-ovarian failure from the T1 to T2 timepoints, and that the control mice would demonstrate similar stiffness at the T1 and T2. It was also expected that the VCD-training mice would maintain more stiffness compared to VCD-sedentary mice, especially within the T2 group. Unexpectedly, the VCD-training mice had less stiff spines compared to the control mice at the T2 timepoint. Further, rather than the lower stiffness at T2 compared to T1 occurring only in the VCD groups, a similar finding was also observed in the control-sedentary group. This timepoint difference suggests that age, more so than VCD treatment, has a significant impact on spine stiffness in these mice. Additional research is needed to further investigate this phenomenon and the implications surrounding it. Our histological testing will help us further probe the unexpected mechanical testing results.

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COMPARING THE EFFECTS OF FEMALE SEX HORMONES ON LUMBAR SPINE AND HIP PASSIVE STIFFNESS

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Introduction: The ovulation phase of the menstrual cycle, influenced by a peaking of estrogen, is associated with decreased soft tissue stiffness and increased laxity leading to ligamentous and muscular injuries. These ligamentous and postural effects are widely studied in knee and ACL injuries. [1] [4] Previous research also links seated and flexed lumbar postures with changes in lumbar mechanics and stiffness (increased and decreased), to lumbar injury development [2]. All of which justify an investigation of injury risk from lumbar, and possibly hip, passive stiffness changes during female hormonal cycles.

Aim: The purpose of this study is to investigate the effects of the female hormone cycle on lumbar spine and hip passive stiffness and posture. Specifically, to see if the follicular, ovulatory and luteal phases, driven by changes in sex hormones, influence these variables. Results from this study will provide a better understanding of females' passive lumbar stiffness and insights into low back pain susceptibility across the menstrual cycle, particularly posture-related in ergonomic settings.

Methods: Passive lumbar and hip stiffness of 20 females, not taking hormonal contraceptives, will be measured three times throughout the menstrual cycle. Participants will get secured and pulled into maximum lumbar and hip flexion, in custom jigs, composed of an immobile platform and a mobile platform that can move over a near-frictionless surface. Lumbar posture will be assessed with two randomized 5-minute trials of standing and seated typing. Breakpoint analysis will be used to partition the lumbar/hip moment-angle curve into low, transition and high stiffness zones. Two breakpoints will be found, indicating where tissue stiffness abruptly changes, and average passive stiffness of each zone will be found using the breakpoint analysis algorithm. A repeated measures ANOVA will be used to determine any main effects of menstrual cycle phase on passive stiffness or lumbar posture. Participants blood will be taken during each session and later analyzed using enzyme-linked immunoassay (ELISA) to quantify estradiol levels and confirm menstrual phase.

Expected Results: It is hypothesized that females will experience fluctuations in lumbar spine, and possibly hip, passive stiffness across the phases of the menstrual cycle, where it is expected that they will have the lowest passive stiffness during the ovulation phase. It is also hypothesized that there will be changes in the average or peak seated and/or standing sagittal lumbar spine postures that correlate with increased lumbar spine passive stiffness during the ovulation phase.

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ACTIVE AND PASSIVE CONTRIBUTIONS TO THE PROPAGATION OF IMPACT ACCELERATIONS THROUGH THE LUMBAR SPINE DURING 2-FOOT LANDINGS

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Introduction: Exposure to impact-related accelerations in the lumbar spine is thought to contribute to low back pain [1]. These accelerations may be attenuated through multiple mechanisms, but their roles in the spine are debated. Diurnal variation also alters spine passive properties [2].

Aim: This study will explore how sex, diurnal variation, standing lumbar lordosis, dynamic lumbar lordosis, active trunk stiffness, passive lumbar flexion stiffness, and intervertebral disc height influence accelerations through the lumbar spine to quantify active and passive contributions *in vivo*.

Methods: Thirty-two back-healthy adults (16 male, 18-35 y) will be recruited. Accelerations will be initiated via 2-foot landings: (1) a standing heel-drop, (2) a countermovement jump, and (3) a drop from dead-hang. Landings will occur within 1 h of waking (AM) and 8-10 h after waking (PM). Temperature and humidity will be adjusted for AM landings to mitigate diurnal muscle differences [3]. Accelerations at the S1 and T12 levels will be measured with triaxial ADXL 377 accelerometers (Analog Devices, MA, USA); muscle activation of two trunk flexors and extensors will be measured bilaterally with an AMT-8 amplifier system (Bortec, AB, CA); and lumbar spine kinematics will be measured using an Optotrak active motion capture system (Certus & 3020, NDI, ON, CA). Standing lordosis angle will be recorded, as well as the dynamic lordosis angle (mean, ROM, and mean angular velocity) during the landings. Active stiffness will be inferred using a measure of co-activation [4]. Passive stiffness will be measured in side-lying [5]. Dual x-ray absorptiometry will be used to obtain intervertebral disc height (Horizon® A, Hologic, MA, USA). Acceleration propagation will be reported as the mean difference between S1-to-T12 (dB) in the axial, transverse, and resultant components during impact. Mixed ANOVAs will be used to test if diurnal variation (AM/PM) and sex (male/female) influences propagation. Multiple linear regressions using the all-possible-regressions procedure will determine variance explained by active and passive mechanisms diurnally (α=0.05) (SAS Studio V3.81).

Expected Results: Sex differences are expected given findings in gait [6] and mixed reports of sexual dimorphism in lordosis [7]. No significant effect of diurnal variation on acceleration in any axis is expected, given that active mechanisms are hypothesized to be the main contributor [8]. Both active and passive mechanisms are expected to significantly correlate with acceleration propagation, with active mechanisms explaining greater variance compared to passive mechanisms [8].

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USING THE KINETIC PROFILE OF VERTICAL JUMPING TASKS TO CHARACTERIZE FIELD HOCKEY CANADA'S FEMALE HIGH-PERFORMANCE DEVELOPMENT PATHWAY ATHLETES

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Introduction: Field Hockey Canada's NextGen program supports player development across age cohorts (i.e., U16, U18, U23) towards the national team. A need has been identified to characterize physical development and athletic ability in female athletes to assess whether sex- and age-specific supports are necessary to optimize development and performance potential. Through collaboration between researchers and knowledge users, it was decided that quantifying and comparing vertical jump (VJ) mechanics across age cohorts would serve as a first step. This decision was informed by literature supporting the use of VJ height (movement outcome) and associated ground reaction force–time (F-T) characteristics (movement processes) to assess: performance status; adaptations to training programs; athletic ability; and physical strengths and weaknesses [1].

Aim: The primary purpose of this in-progress study is to use the VJ as an assessment tool to identify if differences exist between the age cohorts in the high-performance development pathway in F-T profiles to inform training design and implementation. A secondary purpose is to begin building knowledge translation (K-T) capacity within the NextGen program.

Methods: Thirty-seven female (10 U18; 20 U23; 7 Senior) field hockey athletes performed 10 countermovement and 10 squat VJs in a randomized order and with maximal effort. Jumps were performed on two force plates (BP600900, AMTI, MA, USA) and vertical ground reaction force data was collected using NetForce data acquisition software (AMTI, MA, USA) at 1000Hz. In addition to jump height, take-off velocity, peak force, time-to-peak force, average and peak rate of force development (RFD), and net impulse will be calculated. These dependent variables will be compared at the group level using a repeated-measures ANCOVA, with body weight serving as the covariate. Practitioners from the NextGen program (i.e., knowledge users) were involved in the production of the research question and data collection methodology to ensure the research recommendations could be directly applied to their athlete population.

Expected Results: It is hypothesized that F-T profiles will differ between athletes. In comparison to the U18 cohort, Senior and U23 athletes will exhibit higher values across dependent variables previously shown to correlate with physical ability and performance potential. Further, dependent variables associated with movement processes (e.g., peak RFD and net impulse) may provide better insight into between-participant variability over performance outcome variables (e.g., jump height). The findings of this research may help to better identify and distinguish differences among the different age cohorts and support training and monitoring program design for these developmental pathway athletes. Further, the use of this integrated K-T approach should improve the relevancy, quality and impact of the research findings [2].

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AGREEMENT AND RELIABILITY OF PANORAMIC COMPARED TO SITE-SPECIFIC B-MODE ULTRASOUND OVER THE LATERAL HIP

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Introduction: Soft tissues overlying the greater trochanter (GT) significantly influence impact force on the hip and can be used to estimate hip fracture risk [1]. Site-specific B-mode ultrasound (SSU) is a reliable method for measuring tissue thickness [2]. Panoramic B-mode ultrasound (PU) is an alternative method that captures greater tissue area, but no studies have investigated its reliability and validity in measuring soft tissue-specific thickness over the lateral hip. This study aimed to assess: 1) agreement between lateral hip soft tissue thickness measured by PU and SSU imaging, and 2) the intra-rater reliability of tissue thickness from the PU images.

Methods: Three SSU and two PU images were acquired at the GT and 6 cm distal to the GT (L3) in 16 healthy adults using a GE LOGIQ E10 ultrasound machine with a linear array probe (GE Healthcare Canada, ON, Canada). Muscle, adipose, and total tissue thicknesses (MT, AT, TT, respectively) were extracted from images of both modalities. Potential differences in thicknesses between modalities were assessed with paired T-tests. Intra-class correlation coefficients with absolute agreement ($ICC_{3,1}$) were calculated for PU tissue thickness measures.

Results: Tissue thicknesses across PU and SSU images were significantly different for all tissues except GT MT and L3 AT with mean thickness differences for each tissue being within 3.4-15% (Figure 1). AT and TT showed excellent reliability at both points (ICC > 0.9) while MT showed good reliability at GT (ICC = 0.75 - 0.9) and poor reliability at L3 (ICC < 0.5) (Table 1).

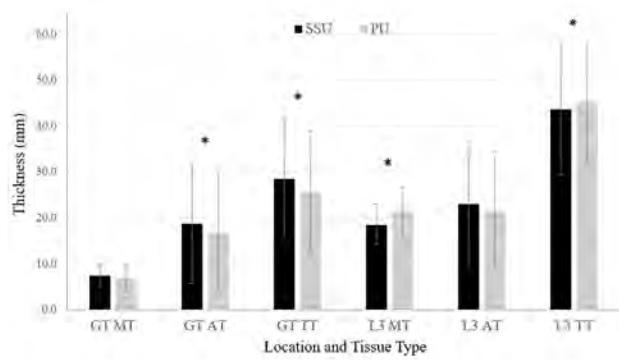

Figure 1: Mean (SD) thickness between PU and SSU images for each location and tissue type (* indicates p<0.05)

Discussion: Panoramic ultrasound (PU) exhibited strong reliability indicating its ability to consistently measure soft tissue thickness over the lateral femur. Although significant differences between PU and site-specific ultrasound (SSU) were observed in 4 of 6 conditions, the mean difference in TT at the GT (2.77 mm) was smaller than the mean difference in trochanteric soft tissue thickness between hip fracture patients and controls (9.4 mm) reported previously [1], suggesting the difference in methods may not be clinically significant. These results support PU as a potential alternative to SSU for measuring soft tissue thicknesses at the lateral hip.

Resources:

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Table 1: Intra-rater reliability (ICC and 95% CI) between PU images across locations and tissue types

	ICC Value	Lower	Upper		ICC Value	Lower	Upper
GT MT	0.899	0.740	0.963	L3 MT	0.434	-0.041	0.754
GT AT	0.976	0.932	0.991	L3 AT	0.974	0.927	0.991
GT TT	0.983	0.954	0.994	L3 TT	0.905	0.757	0.966

ANALYSIS OF STRAINS IN THE CERVICAL SPINAL CORD DURING FRONTAL, LATERAL AND REAR IMPACT SCENARIOS

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Introduction: Despite global efforts to mitigate injury, Spinal Cord Injuries (SCIs) remain a large burden with high socio-economical costs. The leading cause of SCIs is automobile accidents, accounting for almost one third of all SCIs [1], with 55% of all SCIs occurring in the cervical spine [2]. Finite Element (FE) human body models (HBMs) provide unique opportunities to investigate deformations induced in the nervous tissues in simulated impact scenarios. A recent implementation of an anatomically accurate and biofidelic spinal cord in the 50th percentile male (M50) FE HBM (GHBMC M50-O version v5.1) enables simulation of deformations occurring in the spinal cord during impact scenarios [3]. This study re-created frontal, later and rear impacts from experimental data [4] using the M50 model. The strains occurring in the spinal cord were evaluated and compared to a literature injury threshold value [5].

Methods: The detailed FE Head and Neck model (GHBMC M50-O v5-1) with cervical neural tissues including: the spinal cord, pia mater, dura mater, CSF and neural ligaments, was simulated in 15g frontal (15gFRT), 7g rear (7gREAR), and 7g lateral (7gLAT) impact scenarios. The experimental kinematic curves of the 1st thoracic vertebra were used as inputs to the model [3]. The deformations in the spinal cord tissue were assessed using the traditional 95th percentile MPS (MPS_{95}) metric, and in the form of cumulative-strain curves. For the cumulative-strain curves, each element of the spinal cord the maximum principal strain (MPS) and initial tissue volume were calculated. Secondly, the elements were sorted in order of increasing MPS. Finally, the cumulative strain-volume curves were plotted.

Results: The highest cumulative-strain response was observed in the 15g frontal case, which was also reflected in the highest value of the MPS_{95} (0.198). In the lateral and rear impact scenarios, the cumulative volume-strain curves were similar (orange and black curves) and also demonstrated similar values of MPS_{95}.

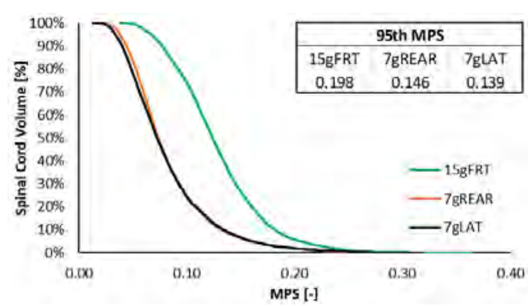

Figure 1: The cumulative volume-strain curves of the spinal cord in the 15g frontal, 7g rear, 7g lateral and the MPS_{95} summary table.

Discussion and Conclusions: One experimental study [5] recognized that stretching an axon beyond 20% caused irreversible damage to transmit nerve impulses. The calculated MPS values in the spinal cord indicate that the neurological sequala may be observed in the occupant that experienced a severe frontal crash. In the rear and lateral impact scenarios, most of the spinal cord volume (>98%) did not surpass the 20% strain, which supports low probability of injury. This study quantified strains in the spinal cord during impact scenarios and attempt to predict SCI occurrence.

References:

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