11th Annual

OBC

ONTARIO BIOMECHANICS CONFERENCE 2014

14th-16th March 2014
Kempenfelt Conference Centre
Barrie, Ontario

Hosted by:

YORK UNIVERSITÉ UNIVERSITY

UNIVERSITY OF TORONTO

Welcome to OBC 2014!

We are excited to welcome everyone to the 11th Annual Ontario Biomechanics Conference at the Kempenfelt Conference Centre, home of OBC for the last 7 years. We have an exciting, full weekend that includes 13 universities, over 153 attendees, and 90 presentations.

OBC has grown dramatically over the last 11 years along with the number of biomechanics faculty in the province (26 are here this weekend). We all owe a debt of gratitude to the founders of the conference, Drs. Jack Callaghan (Waterloo) and Peter Keir (McMaster) for starting this tradition.

OBC has always been designed as a student-first conference. All presentations except for the keynote will be given by students from the undergraduate, masters, and doctoral levels. All sessions will be chaired by doctoral students, and the unwritten expectation is that students will produce most of the questions asked in response to the podium presentations.

We have preserved as much free time as possible on Saturday to allow exercise and reunions or opportunities to make new friends or research colleagues. Social events on both evenings are also a great chance to network with attendees from across the province.

Notes for podium presenters:

We are very much looking forward to your presentations! You will have seven minutes. Session chairs will signal when one minute is remaining, and will stop the presentations at seven minutes. There will then be three minutes for questions. Please upload your presentation in Centre Hall on Friday evening if possible. Day participants can upload their presentations during breakfast or at the first break on Saturday.

Notes for poster presenters:

We anticipate great discussions at your posters! For the Friday poster session please put up your poster as soon as you register. Posters from the Friday session should be taken down before Saturday free time, so that Saturday's poster presenters can put up their posters during free time. You will have 45 seconds to introduce your posters during introduction sessions.

Finally, we must acknowledge the generous contributions from sponsors to the 2014 Ontario Biomechanics Conference. The event would not have been possible without their support.

- The Faculty of Kinesiology and Physical Education at the University of Toronto provided substantial financial contributions and in-kind support from staff.
- The Faculty of Health and Vice-President Research and Innovation at York University provided substantial financial contributions.
- The Canadian Society for Biomechanics continued their support for regional meetings and provided a generous financial donation towards this year's event.
- The Centre for Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD) provided a generous financial contribution to support the Keynote Lecture, Friday dinner, and also several CRE-MSD Student Travel Awards.

Your OBC 2014 organizers:

Janessa Drake and Anne Moore, York University
Tyson Beach and Karl Zabjek, University of Toronto

Ontario Biomechanics Conference Program-at-a-Glance
14th-16th March 2014

Friday 14th March 2014

4:00 - 6:00	Registration		
5:30 - 7:00	Dinner		
7:00 - 7:10	Opening Remarks		
7:10 - 8:00	Keynote	Dr. Stuart McGill	Professor, Waterloo
8:00 - 8:15	Poster Introductions		
8:15 - 9:15	Poster Session I	Bring mugs/water bottle for the drink station. Snacks will be provided.	
9:15 - ?	Social		

Saturday 15th March 2014

			Session Chairs
7:30-8:15	Registration		
7:15 - 8:30	Breakfast		
8:30 - 9:30	Podium Session A	Tissue Mechanics and Injury	Justin Chee (Toronto), Alison McDonald (McMaster)
9:30-9:45	Break		
9:45-10:45	Podium Session B	Posture, Gait, and Balance I	Neha Arora (McMaster), Brian Nairn (York)
10:45-11:00	Break		
11:00-12:00	Podium Session C	Occupational Biomechanics and Musculoskeletal Disorders	Patrick Antonio (Toronto), Alison Schinkel-Ivy (York)
12:00-1:30	Lunch		
1:30-2:20	Podium Session D	Methods, Instrumentation, Analysis, Modelling I	Colin McKinnon (Waterloo), Mike Sonne (McMaster)
2:20-2:35	Break		
2:35-3:25	Podium Session E	Clinical Biomechanics, Rehabilitation, and Fitness	Nicholas Brisson (McMaster), Marcus Yung (Waterloo)
3:25-3:40	Poster Introductions		
3:40-6:00	Free Time		
6:00-8:00	Dinner		
8:00-9:00	Poster Session II	Bring mugs/water bottle for the drink station. Snacks will be provided.	
9:00-?	Social		

Sunday 16th March 2014

			Session Chairs
7:30 - 8:30	Breakfast		
8:30 - 9:20	Podium Session F	Methods, Instrumentation, Analysis, Modelling II	David Kingston (Waterloo), Nicholas La Delfa (McMaster)
9:20 - 9:50	Break/Check-out		
9:50 - 11:00	Podium Session G	Muscle	Vicki Komisar (Toronto), Derek Zwambag (Guelph)
11:00-11:10	Break		
11:10-12:00	Podium Session H	Posture, Gait, and Balance II	Kristina Gruevski (Waterloo), Aaron Kociolek (McMaster)
12:00-12:20	Closing Remarks		
12:20-1:30	Lunch	Faculty: please get your lunch and join us for the OBC Wrap-up and Planning meeting	

Ontario Biomechanics Conference Poster Presentations
14^{th}-16^{th} March 2014

Poster Session I: Friday 14^{th} March 8:15pm - 9:15pm
(Poster Introductions 8:00pm)

Poster#	Poster Presenter	Title
1	Alex Kuntz	Modifiable determinants of physical function in older women with knee osteoarthritis
2	Alison Schinkel-Ivy	Characterization of thoracic spine kinematics
3	Amarah Epp-Stobbe	Effect of thigh-calf contract force in predicting knee joint reactions
4	Angelica Lang	Activation patterns of humeral internal and external rotators during axial rotation at varying postures
5	Anthony Gatti	The relationship between the load-bearing surface area of the medial tibial plateau and measures of body size in women with knee osteoarthritis
6	Ben Warnock	Comparison of upper extremity muscle activation levels during isometric and dynamic MVC protocols
7	Benjamin Cornish	Lower limb adaptations to altered kinematic properties in human gait
8	Brian Nairn	Determining MVC techniques for upper-thoracic erector spinae
9	Christopher Nolan	Passive mechanical testing of muscle from mice with spinal ectopic mineralization resembling diffuse idiopathic skeletal hyperostosis
10	Colin McKinnon	Low back and abdominal muscle activity when performing simulated industrial tasks in standing and sitting postures
11	Damjana Milicevic	Adaptations of kinetics during level and obstructed walking when knee range of motion is limited
12	Dan Viggiani	Can inertial measurement units accurately quantify lumbar posture in prolonged tasks?
13	Daniel Martel	Modulation of peak force and peak pressure during a simulated hip impact
14	David Kingston	Influence of tablet or computer and work surface angle on upper limb kinematics
15	Derek Zwambag	Muscle structural and mechanical remodelling in response to lumbar facet joint degeneration in the rat
16	Drazen Glisic	Is there a relationship between patellar tendon stress-time histories and trunk and lower extremity sagittal plane kinematics during a horizontal and vertical deceleration task?
17	Elizabeth Price	Estimation of spinal loading using inertial motion sensors and 3D loading model
18	Elora Brenneman	Evaluation of biomechanical and neuromuscular effects of prophylactic knee brace use following exercise
19	Grace Glofcheskie	Investigating the relationship between hip position and lumbar spine range of motion
20	Justin Chee	Effects of traumatic brain injury on toe clearance during obstacle negotiation in the presence of a visual scanning task
21	Justin Laing	The effect of dual-tasking on compensatory arm responses in young and older adults
22	Vicki Komisar	Two different methods of evoking balance loss in young adults in dynamic conditions: A pilot study

Ontario Biomechanics Conference Podium Presentations
14^{th}-16^{th} March 2014

Podium Sessions A-E: Saturday 15^{th} March 8:30am - 3:25pm

Podium Session	Presenter	Title
A: Tissue Mechanics and Injury Saturday 15^{th} March 8:30am – 9:30am	Danielle Stewart	The tensile properties of single lamella from lamb annulus fibrosus
	Kathleen MacLean	Reliability of white light interferometry for assessing bone surface morphology
	Kayla Fewster	Exploring the regional response of the intervertebral disc under postural varying loads
	Lauren Monaco	Comparative analysis of biomechanical and anatomical properties of the intervertebral disc from three model species
	Mamiko Noguchi	Intradiscal pressure response during intervertebral disc herniation
	Thomas Karakolis	Implications of biaxial tensile testing for modeling the mechanical behaviour of the annulus fibrosis
B: Posture, Gait and Balance I Saturday 15^{th} March 9:45am – 10:45am	Amy Hackney	Is the critical point for aperture crossing adapted to the person-plus-object system?
	Chris Shaw	Adults with multiple sclerosis require balance- and proprioceptive- specific exercises to elicit continued improvement in static balance
	Glynnis Pardo	Energy adaptations of the trunk during transitions from level to inclined surfaces
	Helen Chong	Does a constrained ankle joint affect the flexion angles of the knee?
	Kaitlin Gallagher	The influence of lower limb position on the lumbar spine in three upright standing positions
	Tyler Weaver	Stooping and crouching postures: The applicability of the inverted pendulum model
C: Occupational Biomechanics and Musculoskeletal Disorders Saturday 15^{th} March 11:00am – 12:00pm	Alan Cudlip	Upper extremity muscular demands during materials handling tasks while sitting and standing
	Jessica Cappelletto	Lower-body bracing during kinematically constrained tasks
	Julian Liebregts	Right angle power tool physical demands with assembly work
	Scott Dainty	Joint loading, postures and the link with pain reporting during the preparation of espresso-based beverages
	Spencer Savoie	Dynamic shoulder strength prediction for ergonomic applications
	Tara Diesbourg	Spinal loads in daycare workers when lifting children: A pilot study
D: Methods, Instrumentation, Analysis, Modelling I Saturday 15^{th} March 1:30pm – 2:20pm	Alex MacIntosh	Modelling the index finger: A comparison of computational methods to assess joint loading with submaximal dynamic tasks
	Binh Ngo	Testing forearm EMG protocols for normalizing grip strength
	Danielle Devries	The authentication of a human posture prediction tool used for virtual ergonomic analyses
	Jaclyn Chopp-Hurley	Probabilistic evaluation of predicted force sensitivity to muscle attachment and glenohumeral stability uncertainty
	Malinda Hapuarachchi	A construct validity study of the Functional Movement Screen™
E: Clinical Biomechanics, Rehabilitation, and Fitness Saturday 15^{th} March 2:35pm – 3:25pm	Ayesha Johnson	Relationships between knee kinematics and the knee adduction moment in yoga postures
	Brendan Cotter	Can insoles reduce ground reaction forces?
	Iris Levine	The influence of body geometry and soft tissue distribution on distribution of loads during impacts to the hip
	Meagan Warnica	Characterizing cycling/motor vehicle accidents causing litigation in Southern Ontario
	Mike Davison	Thigh intramuscular fat is related to decreased knee extensor and flexor power in women with knee osteoarthritis

Ontario Biomechanics Conference Poster Presentations
14th-16th March 2014

Poster Session II: Saturday 15th March 8:00pm - 9:00pm
(Poster Introductions 3:25pm)

Poster#	Poster Presenter	Title
23	Corinne Babiolakis	Relationship between active hip abduction test and standing balance
24	Daniel Vena	Characterizing signal properties of the channeling portion of pedicle screw insertion
25	Erika Lee	Evaluation of exercise rehabilitation in persons with spinal cord injury
26	Jacquelyn Maciukiewicz	Shoulder and low back loading in cashiers: What are the critical contributing factors? A laboratory study
27	Kaitlin Jackson	Does isometric strength training decrease valgus angle during a drop-jump landing in elite female volleyball players?
28	Kristina Gruevski	The effect of local hydration environment on temporal changes in annular thickness and mass
29	Mani Sadeghzadeh	EMG changes of the forearm extensor muscles at different postures
30	Marcus Yung	Identifying measures of fatigue - the CRE-MSD Toronto Workshop
31	Mario Boivin and Devon Day	Neuromechanical control of dual-tasking
32	Marissa Canning	Can plantar cutaneous stimulation via vibration facilitate walking/standing in individuals with an incomplete spinal cord?
33	Maureen Riddell	Influence of input device, desk configuration, and task on spine kinematics
34	Neha Arora	Is knee osteoarthritis a risk factor for non-specific low back pain during lifting?
35	Nicole Green and Elizabeth McLeod	The role of plantar cutaneous mechanoreceptors during gait
36	Patrick Antonio	Investigating the effects of balance, plantar pressure and cutaneous sensitivity in diabetic individuals during stair gait
37	Peter Sheahan	Evaluating the effect of rest breaks on productivity, discomfort, and trunk postural control during prolonged seated typing
38	Reza Khiabani	Association between spasticity and balance impairments in persons post-stroke
39	Sebastian Tomescu	Filtering revisited: Cutoff frequency effects on musculoskeletal simulations
40	Stewart Chisholm	Activities of daily living for unilateral transfemoral amputees: An evaluation of kinematics, kinetics, and trunk muscle activity
41	Tatjana Stankovic	The inter-rater reliability of a novel battery of range-of-motion tests
42	Taya McGillivary	Relationship between the starting angle of thigh-calf contact and anthropometric measures between sex and high-flexion activities
43	Tyler Saumur	Increasing strength through the power of visualization
44	Sulahb Singh	Effects of foot orthotics on spine kinematics during gait and kinetics during free style lifting

Ontario Biomechanics Conference Podium Presentations
14th-16th March 2014

Podium Sessions F-H: Sunday 16th March 8:30am – 12:00pm

Podium Session	Presenter	Title
F: Methods, Instrumentation, Analysis, Modelling II Sunday 16th March 8:30am – 9:20pm	Chris Bailey	An accelerometer as an alternative to a force plate for the step-up-and-over test
	Lindsay Musalem	Biomechanical and electromyographic comparison of isometric trunk flexor endurance tests: Prone "plank" vs. "v-sit"
	Paul Makhoul	Inter- and intra- rater reliability of shoulder range of motion measures when wearing a bomb blast protection suit
	Shawn Beaudette	The dynamic stability of the lumbar spine: A controlled kinematic outcome
	Steven Khuu	The effects of verbal instructions on drop-jump biomechanics implications for athletic performance and injury risk assessment
G: Muscle Sunday 16th March 9:50am – 11:00am	Alex Waugh	The effect of motor imagery on the co-contraction and recruitment timing of vastus lateralis/vastus medialis obliquus during simple knee flexion-extension exercises
	Dan Mines	Lower leg net muscle activation during kneeling transitions: Comparing effects of mass and location of load
	Diana De Carvalho	Deep low back muscles are not a factor in sitting related pain
	Greig Inglis	Sex-related differences in the rate of torque development in the human tibialis anterior
	Lydia Frost	Lower back and lower limb neuromuscular structure and function in chronic low back pain patients with associated radiculopathy
	Nicole Hills	The relationship between changes in abdominal muscle thickness measured on ultrasound images and muscle activation recorded using fine wire electromyography: A validation study
	Steve May	Effect of wrist posture and rate of force development on finger control and independence
H: Posture, Gait and Balance II Sunday 16th March 11:10am – 12:00pm	Dorelle Hinton	Reaching the limits of cognitive resources: Coping strategies used by children during a multi-task paradigm
	Emily McIntosh	Knee range of motion influences obstacle avoidance strategies in the sagittal plane during gait
	Hannah Moore	Training effects of Tai Chi and compensatory stepping on balance control in older adults
	Liana Tennant	How do work boots affect the location of centre of pressure at the knee during static kneeling?
	Luke Denomme	Individuals with multiple sclerosis with mild balance impairment display similar postural and dynamic balance control characteristics to community-dwelling older adults

Ontario Biomechanics Conference Presentations

14th-16th March 2014

Abstracts by Session

Ontario Biomechanics Conference Poster Presentations
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MODIFIABLE DETERMINANTS OF PHYSICAL FUNCTION IN OLDER WOMEN WITH KNEE OSTEOARTHRITIS

A. B. Kuntz, E. G. Wiebenga, E. C. Brenneman, H. S. Longpre, M. R. Maly
School of Rehabilitation Science, McMaster University, Hamilton, ON

Purpose: The Osteoarthritis Research Society International (OARSI) recently published guidelines for assessing physical function in people with knee OA through a battery of mobility performance-based tests [1]. The purpose of this study was to determine the importance of muscle strength, aerobic fitness, and body mass index (BMI) on the performance of these tests.
Methods: Nineteen women with symptomatic knee OA participated (mean ± standard deviation (SD) age=60.5±4.5 years). The physical function tests included a 30 second chair stand, 40 metre fast-paced walk, stair ascent, stair descent, and six minute walk. Muscle strength was represented by peak torque during a voluntary maximal isometric contraction of the knee extensor muscles on the Biodex System 2 dynamometer (Biodex Medical Systems Inc., Shirley NY USA) and expressed relative to body mass (Nm/kg). Aerobic fitness was quantified by predicted maximal oxygen consumption (VO_2 max, mL/kg/min) from a submaximal test (YMCA protocol) on a Lode Excalibur Sport 925900 cycle ergometer (Lode, Groningen Netherlands). BMI was calculated from body mass and height (kg/m^2). Pearson correlation coefficients examined relationships between variables. Linear regression analyses were completed. Mobility measures were dependent variables and strength, fitness, and BMI, were independent variables.
Results: Mean ± SD for the 30 second chair stand, 40 metre fast-paced walk, stair ascent, stair descent, and six minute walk test values were 13±4 repetitions, 25.2±4.2 s, 4.7±1.6 s, 4.2±1.3 s, and 541±83 m, respectively. Mean ± SD for peak knee extensor torque, predicted VO_2 max, and BMI values were 107.8±25.7 Nm/kg, 26.0±5.5 mL/kg/min, and 29.8±4.8 kg/m^2, respectively. Strength was important to performance of all tasks; while fitness appeared most important to performance of the stair ascent and six minute walk (Table 1).
Conclusion: Muscular strength, aerobic fitness, and BMI appear important to physical function in older women with knee OA. Strength and fitness values were low, while BMI values were high, in this sample relative to healthy older women. To improve mobility, treatment should emphasize increasing strength and fitness, while decreasing BMI.
Reference: [1] Dobson, F., et al. (2012). *Osteoarthritis and Cartilage* (20); p. 1548-62

Table 1. Correlation and regression analyses of physical function tests vs. predictors

Physical Function Test	Predictor	Pearson r	Adjusted R^2	Standardized β Coefficient	p
30 Second Chair Stand (repetitions)	Strength	0.429	0.370	0.404	*0.048
	Fitness	0.548		0.431	0.125
	BMI	-0.466		-0.140	0.604
40 m Walk (s)	Strength	-0.526	0.443	-0.502	*0.012
	Fitness	-0.521		-0.396	0.133
	BMI	0.450		0.145	0.570
Stair Climb Ascent (s)	Strength	-0.560	0.544	-0.536	*0.004
	Fitness	-0.576		-0.524	*0.035
	BMI	0.438		0.041	0.860
Stair Climb Descent (s)	Strength	-0.703	0.671	-0.679	*< 0.001
	Fitness	-0.432		-0.139	0.480
	BMI	0.504		0.373	0.071
6 Minute Walk (m)	Strength	0.647	0.819	0.615	*< 0.001
	Fitness	0.659		0.452	*0.006
	BMI	-0.605		-0.254	0.094

* p values are < 0.05

CHARACTERIZATION OF THORACIC SPINE KINEMATICS

Alison Schinkel-Ivy, Janessa D.M. Drake
School of Kinesiology and Health Science, York University, Toronto, ON

Introduction: The lumbar spine has been extensively characterized in terms of range-of-motion and resultant loading patterns. However, there is a paucity of work relating to the thoracic spine, and as such, a thorough investigation of thoracic spine mechanics seems warranted. The thoracic spine has been defined in various ways in past work; however, to the authors' knowledge, no study to date has examined the ideal segments necessary to sufficiently characterize the thoracic spine, during various trunk movements in all three planes of motion. Therefore, this study aimed to determine the necessary and optimal segments required to characterize the kinematics of the thoracic spine.

Methods: Thirty individuals, free of low back pain, performed ten trials of eight postures: maximum trunk flexion, lateral bend, and axial twist; thoracic flexion, lateral bend, and axial twist; and upright and slumped standing. Clusters of five passive-reflective markers were applied over the C_7, T_3, T_6, T_9, T_{12}, and L_5 vertebrae. The three-dimensional angles of each cluster relative to the global coordinate system were calculated. Cross-correlations were performed for each adjacent pairing of clusters to obtain maximum cross-correlation coefficients (R_{xy}) and time lag at R_{xy} ($R_{xy}(\tau)$). Very strong correlations ($R_{xy}>0.95$) indicated that one of the two clusters could be eliminated, as determined by anatomical significance and commonalities between adjacent cluster pairings.

Results: During upright standing, some clusters were strongly correlated in terms of flexion-extension angles, while lateral bend and axial twist angles typically exhibited coefficients of very weak to weak strength. Very strong correlations (R_{xy} ranging from 0.9658 to 0.9995) were identified between many of the adjacent clusters (20 of 35 total comparisons) during the movement trials. It was determined that a four-cluster marker set (C_7, T_6, T_{12}, L_5) sufficiently captured thoracic motion for most postures, with the exceptions of upright lateral bend and axial twist angles (six clusters), and thoracic twist (five clusters).

Discussion and Conclusions: Past work has identified strong relationships in cervical and thoracic motion [1] and in thoracic and lumbar motion [2]. The present results agreed, identifying very strong correlations in the motion of many of the adjacent clusters during the movement trials. The locations of the markers in the optimal set corresponded to the boundaries of the thoracic and lumbar regions, and the approximate apex of the thoracic spine. Therefore, a marker set consisting of clusters at the C_7, T_6, T_{12}, and L_5 vertebrae are likely sufficient to capture thoracic motion.

References: [1]Tsang et al. (2013). *Man Ther* 18(5):431-7. [2]Johnson et al. (2010). *Clin Biomech* 25:199-205.

EFFECT OF THIGH-CALF CONTACT FORCE IN PREDICTING KNEE JOINT REACTIONS

Amarah Epp-Stobbe[1], Taya McGillivary[1], Stacey Acker[1]
[1]Applied Health Sciences, Kinesiology, University of Waterloo, Waterloo, ON

Introduction: With the dramatic increase in total knee arthroplasties in Canada in patients between 45 and 55 years of age, of 337% between 1996-1997 and 2006-2007 [1], the creation of knee joint implants that can withstand the demands of the user's lifestyle which may include activities done in deep flexion is crucial. In deep flexion, thigh-calf contact force generates a moment in the same direction as the moment created by the quadriceps' tendon, thereby, reducing the amount of force required by the quadriceps [2]. Previous models of the knee joint in deep flexion have relied on thigh-calf contact force estimates [2, 3]. The accuracy of this predictive measure has not yet been compared to direct measures. The predicted knee joint forces tend be higher as the knee flexion angle increases since thigh-calf contact is often neglected in musculoskeletal models [3]. The importance of thigh-calf contact magnitude must then be integrated into existing ground reaction force-based models to determine if a significant relationship between measure ground reaction force and measured thigh-calf contact magnitude exists.

Aim: This study will assess the effect of including thigh-calf contact force in the prediction of knee joint reactions using an inverse dynamics based rigid link-segment model in squatting, dorsi-flexion kneeling and plantar flexion kneeling.

Methods: Thirty healthy participants, fifteen males and fifteen females, will be recruited from the local population. Knee flexion angles will be measured using a motion capture system (Northern Digital Incorporated, Waterloo, ON). Thigh-calf contact pressures will be recorded and processed using a pressure mapping sensor and software (XSensor, Calgary, AB). Forces occurring at the ground will be measured using a force plate (Advance Mechanical Technology Inc., Watertown, MA.) and processed using Visual 3D software (C-Motion Incorporated, Germantown, MD). Participants will take part in three trials of a randomized order of the three activities. A Bland-Altman test for the level of agreement between net joint moment accounting for the thigh-calf contact force and neglecting the thigh-calf contact force will occur using MATLAB software (The MathWorks Incorporated, Nattick, MA).

Expected Results: It is expected that there will be a significant difference between joint reactions about the knee that include thigh-calf contact force and those that exclude thigh-calf contact force. Previous studies have noted that thigh-calf contact force produces a substantial effect on the predictions for internal loads at the knee [2,3]. Intra-participant thigh-calf contact force variability should not be significantly different across the three activities according to the work of Zelle et al. [3]. The results of the proposed research may provide the basis for the clearer development of predictive models for tibiofemoral joint forces that include both ground reaction forces as well as thigh-calf contact characteristics. The results may also be expanded upon to validate or disprove previous models in which ground reaction force was used to develop a regression equation predicting thigh-calf contact force [2].

References:
[1] Canadian Institute for Health Information (CIHI). Hip and Knee Replacements in Canada – Canadian Joint Replacement Registry (CJRR) 2008-2009 Annual Report; CIHI, 2009.
[2] Caruntu D. L. et al. (2003). Modeling the knee joint in deep flexion: "Thigh and calf" contact. 2003 Summer Bioengineering Conference; Key Biscayne, Florida.
[3] Zelle, J. et al. (2007). Thigh-calf contact force measurements in deep knee flexion. Clinical Biomechanics 22 (7); p. 821-826.

ACTIVATION PATTERNS OF HUMERAL INTERNAL AND EXTERNAL ROTATORS DURING AXIAL ROTATION AT VARYING POSTURES

Angelica E. Lang[1], Xu Xu[2], Jia-Hua Lin[2], Raymond W. McGorry[2], and Clark R. Dickerson[1]
[1]Department of Kinesiology, University of Waterloo, Waterloo, ON
[2]Liberty Mutual Research Institute for Safety, Hopkinton, MA, USA

Background: Musculoskeletal risk is mediated by body posture, especially for static tasks. Injury risk is reportedly four times higher when workers have high exposure to non-neutral postures (1). Workstations with postural constraints that require non-neutral postures, especially those with work above shoulder height, can lead to increased load, muscular fatigue and injury risk, as well as a decreased endurance and force production (2). However, the muscular demands consequent from performing even simple tasks, such as axial humeral rotation, are ill-defined.

Purpose: The purposes are quantification of the muscular activity of consensus shoulder internal and external rotators over an unprecedented range of arm postures and definition of the influence of contraction intensity and direction of effort (internal/external rotation) on muscular demands.

Methods: Nineteen participants performed 80 isometric actions at specific intensities (20% and 40% of both axial internal and external rotation strength), humeral elevation angles (0-30°-60°-90°-120°-150°), and elevation planes (0°-30°-60°-90°-120°) with the elbow flexed at 90°. Seven unilateral (right) muscles (pectoralis major (clavicular and sternal), posterior deltoid, teres minor, infraspinatus, supraspinatus and latissiumus dorsi) were monitored by surface electromyography (EMG). EMG was normalized and integrated and the influences of arm posture and intensity were tested with a 3-way ANOVA.

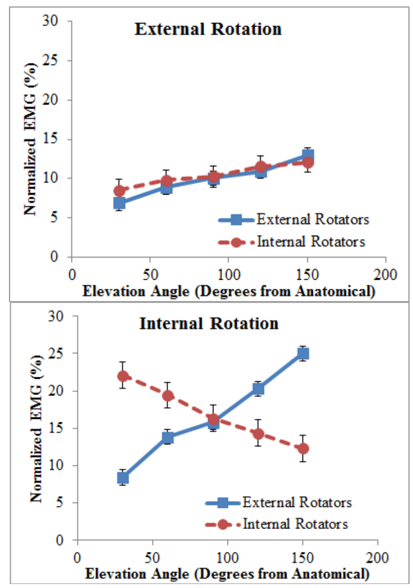

Fig 1. Mean aggregate muscle group activity levels during external (top) and internal (bottom) humeral axial rotation.

Expected Results: Preliminary results indicate different trends depending on the direction of rotation moment. A decrease in internal rotator activity was accompanied by an increase in external rotator activity during internal rotation at higher abduction angles (Figure 1), while both groups increased in external rotation. These changes are likely partly attributable to muscle moment arms changes with humeral elevation. For instance, the infraspinatus moment arm decreases as elevation raises from 10° to 60° (3), leading to an increase in demand for producing the same moment. Plane of elevation had no effect on any muscle group. Task intensity correlated positively with muscle group activations. Considering postural influences on muscular demands can aid job design and provide insight into injury mechanisms. Future analyses will focus on ratios of muscle group co-activation and their relation to joint stiffness and stabilization.

References: [1] Punnett L. et al. 2000. *Scandinavian J Work & Env, Health. 26* (4), 283-291.
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THE RELATIONSHIP BETWEEN THE LOAD-BEARING SURFACE AREA OF THE MEDIAL TIBIAL PLATEAU AND MEASURES OF BODY SIZE IN WOMEN WITH KNEE OSTEOARTHRITIS

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Introduction: Obesity is a risk factor for the incidence and progression of osteoarthritis (OA) of the knee because greater body mass increases forces across the knee. The medial tibial plateau area increases with body mass index (BMI), which is thought to reduce stress on the medial knee[1]. Due to limited regenerative capacity, cartilage may not increase in area along with a widened tibial plateau. The purpose of this study was to determine the relationship between body mass, BMI, height, and abdominal circumference to the area of the medial tibial bone cartilage interface (mtBCI), a measure of the load-bearing surface area of the medial tibial plateau, in women with knee OA. We hypothesized that mtBCI would not be explained by these variables.

Methods: Thirty-nine women (age=61.8 ±6.0 years) with symptomatic knee OA participated. All had radiographic evidence of OA, with Kellgren-Lawrence scores ranging from 1 to 4. Each participant underwent magnetic resonance imaging of the most symptomatic knee using a peripheral 1T scanner (GE Healthcare, USA). Images were segmented using a highly automated atlas-based method. After segmentation, mtBCI surface area was calculated (mm^2). Body mass and height was measured barefoot, wearing a t-shirt and shorts (kg). Abdominal circumference was measured after a maximal expiration half way between the iliac crest and lower rib on a bare torso. Linear regressions were used to analyze the relationship between mtBCI and independent variables of interest.

Results: Participants had a body mass of 72.9 ± 15.5 kg; height of 1.61 ± 0.06 m; BMI of 28.27 ± 5.94 kg/m^2; abdominal circumference of 86.6 ± 15.4 cm and a mtBCI of 889.56 ± 72.30 mm^2. The linear regression models are included in Table 1.

Conclusions: Only height was related to mtBCI. Thus, differences in size of the load-bearing surface area of the medial tibial plateau may be a non-modifiable feature of body size. Research is needed to determine if the bone-cartilage interface adapts to increases in body mass over time.

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Table 1: Simple Linear Regressions of Measures of Body-size to Explain Changes in mtBCI

Model 1					
	β	P	R^2	P	F
Height (m)	754.85	<0.001	0.3643	<0.001	(1,37)=21.20
Model 2					
Body mass (kg)	0.97	0.20	0.04	0.20	(1,37)=1.68
Model 3					
BMI (kg/m^2)	0.31	0.878	<0.001	0.88	(1,37)=0.02
Model 4					
Abdominal Circumference (cm)	0.70	0.37	0.02	0.37	(1,37)=0.84

*** All models follow the format mtBCI= body measure * β + constant**

COMPARISION OF UPPER EXTREMITY MUSCLE ACTIVATION LEVELS DURING ISOMETRIC AND DYNAMIC MVC PROTOCOLS

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Introduction: Muscle activation elicited during maximum voluntary contractions (MVC) is commonly used in biomechanics research to normalize muscle contributions. Isometric MVC protocols may not activate muscles to the same extent as during dynamic activities, such as those involving upper extremity impacts resulting from falling [1]. With the aim of improving our EMG normalization procedures for impact events such as these, the activation levels of several upper limb muscles during isometric and dynamic MVC protocols were compared.

Methods: Twenty four (12 M, 12 F) healthy university-aged participants executed wrist and elbow flexion and extension actions during 5 second MVC protocols targeting six upper extremity muscles (biceps brachii, triceps brachii, anconeus, brachioradialis, flexor carpi ulnaris, extensor carpi ulnaris). The protocols consisted of three repetitions of isometric (ISO) and dynamic (eccentric (ECC), throughout a range of motion (ROM), against elastic resistance (ELASTIC), and concentric, without external resistance (i.e., SELF-contraction)) contractions during two sessions separated by one week. Muscle activation levels were collected using standard EMG preparations, electrode placement and equipment reported previously [1].

Results and Discussion: Overall, the ECC and ROM dynamic protocols consistently elicited higher peak muscle activation levels than the ISO protocol for both male and female participants and during both sessions (Figure 1). Over 95% of the ROM trials resulted in mean and peak muscle activation ratios greater than ISO, suggesting that higher activation levels can be elicited in the muscles evaluated when resistance is applied dynamically through a full range of motion. Utilizing the ROM protocol evaluated here may help to improve MVCs for dynamic upper limb impact research (e.g., [1]).

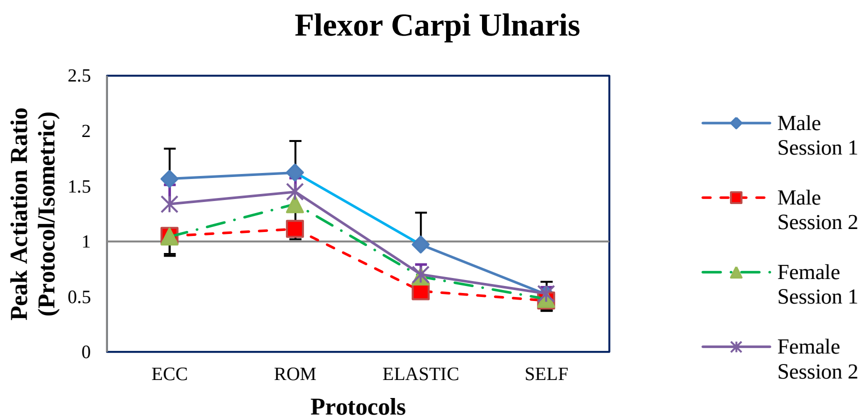

Figure 1: Ratio of the mean peak activation levels for flexor carpi ulnaris as a function of protocol, sex and session. Each value is expressed relative to the values from the isometric protocol for comparison.

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LOWER LIMB ADAPTATIONS TO ALTERED KINEMATIC PROPERTIES IN HUMAN GAIT

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Introduction: Human locomotion is a complex procedure requiring a low amount of concentration in most situations. Three subtasks are necessary to complete successful and safe walking; support from lower limbs against gravity, maintenance of posture and balance and safe trajectory and contact of lower limb through swing phase and initial contact [1]. The complexity of walking is only noticeable when one of the components of the system is compromised [1]. However, our integrated system is capable of adapting to different scenarios, such as: walking on inclined surfaces, loss of functional joints, and altered mechanical properties to maintain these principles. Channels of communication exist between limbs and the CNS, when limb dynamics are altered, these channels allow for a feedback control system to accept sensory feedback signals and produce a motor command that fulfills the aspects of the movement task [2, 3].

Aim: To explore the lower limb adaptation process by examining the instantaneous compensatory reaction to altered kinematic properties (decreased knee range of motion) and to determine how quickly these adaptations take place.

Methods: Testing will include two 15 minute treadmill walking protocols (at 1.56m/s), with each protocol divided into three different five-minute trials. The two protocols will make use of a commercial knee brace that can be modified to limit the amount of flexion. The walking trials will be in the following sequence: without brace, with unlocked brace, without brace, rest, unlocked brace, with brace and flexion stops (at 30 degrees from full extension), and unlocked brace, respectively. Kinematic data of the lower limbs will be recorded using 6 OPTOTRAK (64 Hz; Northern Digital Inc., Waterloo, ON) position sensors. Electromyography will be recorded bilaterally on the thighs and unilateral on the right shank.

Expected Results: Two responses are anticipated for lower limb adaptations. First, a safety response which encompasses changes in the peak ankle dorsiflexion and toe clearance values. It is hypothesized that there will be increases in peak ankle dorsiflexion and hip flexion values to attain necessary toe clearance and compensate for the decrease flexion at the knee joint. The second response should be a recalibration of joint mechanics to obtain a consistent walking pattern. The measurement variability of joint moments and power profiles should progressively decrease over the course of the trial. A similar adaptation response is expected when the participant removes the brace and returns to normal walking patterns [4].

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DETERMINING MVC TECHNIQUES FOR UPPER-THORACIC ERECTOR SPINAE

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Introduction: Normalization of surface electromyography (EMG) to the maximum voluntary contraction (MVC) of a muscle is a common technique used in biomechanics research to allow for appropriate comparison across individuals and tasks. Different MVC techniques for normalizing various trunk muscles in females have been investigated, and included the abdominals, lumbar and thoracic erector spinae (ES) at L5 and T9 respectively, and latissimus dorsi [1]. Recently, five different techniques to obtain an MVC from latissimus dorsi were compared [2]. Additionally, activation of upper-thoracic ES at T4 during the flexion-relaxation response was reported from a modified back extension to obtain MVC values [3]; however full investigation into the MVC techniques of upper-thoracic ES has yet to be conducted. Recent anecdotal evidence from our lab has shown maximal levels of upper-thoracic ES being obtained from postures such as lateral pull-down, instead of the traditional cantilevered back extension. Therefore, the purpose of this study is to determine an appropriate MVC technique for the upper-thoracic ES at the T4 level from various movement patterns.

Methods: Forty participants (20 males, 20 females) free of neck, back, and shoulder pain will be recruited from a university population. Surface EMG will be recorded from 8 muscles bilaterally: left and right upper- and lower- thoracic (T4, T9) and lumbar ES (L3); latissimus dorsi; internal oblique; external oblique; rectus abdominis; and upper trapezius (AMT-8, Bortec, Calgary, Canada). Four different MVC techniques/movement patterns will be presented in a random order: lateral-pull down; seated row; upper-back extension (rotating about mid-back); and cantilevered lower-back extension (hips at bench edge). Each of the ES muscles will be normalized to the absolute peak value obtained from any posture to determine which technique elicited the highest level of activation.

Expected Results and Significance: It is expected that the upper-back extension will produce the largest activations for the upper-thoracic ES muscles as this posture will be the most isolated for that specific trunk region. It is also expected that the lateral pull down and seated row will elicit activations greater than the cantilevered lower-back extension. This study is the first step in a series of investigations into the upper-thoracic region. Results from these data will be used to develop a protocol for fatiguing the upper-thoracic ES muscles independently from the lumbar ES musculature in order to directly compare differences between spine regions during occupational-related tasks.

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PASSIVE MECHANICAL TESTING OF MUSCLE FROM MICE WITH SPINAL ECTOPIC MINERALIZATION RESEMBLING DIFFUSE IDIOPATHIC SKELETAL HYPEROSTOSIS

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Introduction: Diffuse idiopathic skeletal hyperostosis (DISH) is a condition in humans where spinal ligaments are calcified and ectopic mineralization occurs between spinal vertebrae resulting in increased spine stiffness [1]. This condition can be mimicked in mice by knocking out (KO) the *ENT1* gene, which results in calcification of the axial skeleton [2]. Previous research has shown that when intervertebral discs are punctured to initiate degeneration, associated spinal muscle stiffness increases, presumably to counteract the loss in spine stiffness [3]. Thus, it is possible that in situations where spine stiffness is inherently increased (e.g. DISH), muscles will remodel to become more compliant in an attempt to maintain an overall balance in stiffness.

Aim: To determine whether aberrant spine mineralization in the mouse model of DISH is associated with a reduced stiffness of the muscles associated with the spine.

Methods: *ENT1* KO mice will be used as a model of the human condition DISH, as they demonstrate calcification of ligaments and intervertebral disc tissues limiting movement of the spine [2]. Wild-type and *ENT1* KO mice will be euthanized at 4 months of age and the properties of the multifidus muscle tested. The tibialis anterior muscle will also be tested as an internal non-spine control.

Muscle samples will be harvested and individual fibres and bundles of fibres extracted. Samples will be placed in a chamber filled with relaxing solution and attached on one end to a motor to elicit tension in the fibres, and on the other end to a force transducer. A laser will be used to measure sarcomere lengths via diffraction. Each sample will be rapidly stretched approximately 0.25 μm/sarcomere and then held for three minutes before force and length measurements are recorded, to ensure only elastic properties of the sample are tested. From these data a stress strain curve will be plotted and used to determine the elastic modulus of each sample.

Expected Results: Based on the results of previous work in which intervertebral disc degeneration (reduced spine stiffness) resulted in stiffening of the multifidus muscle in rabbits [3], it is expected that multifidus from the DISH mice (with stiffer spines) will be less stiff in comparison to the wild-type mice. Additionally, it is expected that remodeling will occur primarily in the connective tissue that composes the sheath of fibre bundles, thereby resulting in a greater stiffness difference in bundles compared to individual fibres. Finally, as there are no appendicular changes to the skeleton, it is expected that the tibialis anterior will not differ compared to the wild-type samples.

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LOW BACK AND ABDOMINAL MUSCLE ACTIVITY WHEN PERFORMING SIMULATED INDUSTRIAL TASKS IN STANDING AND SITTING POSTURES

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Introduction: Industrial tasks are often performed at non-adjustable workstations. At all design stages, the decision of whether sitting or standing will most effectively reduce musculoskeletal risk factors depends on a variety of acute and cumulative factors. Both prolonged standing and sitting [1] have been linked to musculoskeletal risk with the task type performed also influencing working posture [2]. As a result, both posture and the nature of the task must be considered when assessing physical demands. The purpose of this study was to evaluate trunk muscle activity between sitting and standing while performing two simulated industrial tasks.

Methods: Sixteen participants (8 male; 8 female) were instrumented with surface EMG bilaterally (L/R) over the thoracic (THES) and lumbar erector spinae (LUES), internal oblique (INOB) and gluteus medius (GMED). Participants performed an assembly task (ASSY) and a load transfer task (TRAN) at standing and seated workstations with the work surface adjusted slightly below elbow height. ASSY consisted of placing washers and inserting dowels through pegboard holes. TRAN involved moving a strength-normalized weighted bottle between a series of locations of a flat work surface. EMG recordings were linear enveloped and normalized to maximum voluntary contractions. Median and peak muscle activities were extracted from amplitude probability distribution functions performed on EMG data. Two-way repeated measures ANOVAs assessed the influence of task and working posture.

Results: No significant posture-by-task effects were observed for median or peak muscle activity. For median values, task did not influence any measured muscle activations. Significant whole-posture effects existed for four muscles (p = .002 to p = .037). Muscle activity was higher in standing for the L-INOB, L-LUES, R-INOB, and R-GMED, and in sitting for the L-THES. For peak values, significant posture effects existed for L-INOB, L-LUES, and R-GMED (p = .004 to p = .039), with all showing greater activity in standing. Main effects of task also existed for seven of the recorded muscles (p = .0002 to .012), with all muscles except L-INOB showing higher activity during TRAN than ASSY.

Discussion and Conclusions: The lower trunk muscles were more active while maintaining a standing posture, but thoracic muscles required higher activation while sitting. This higher thoracic activation was perhaps due to the relative absence of using lower trunk and lower limb muscles while sitting. Also, demands resulting from task performance were independent of working posture (no interaction), thus a choice of working posture should focus on balancing the potential metabolic benefits and musculoskeletal disorder risk associated with increased activation. Ongoing more detailed analysis of the muscular activation profiles may provide additional insight into possible mechanisms of increased musculoskeletal injury risk.

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ADAPTATIONS OF KINETICS DURING LEVEL AND OBSTRUCTED WALKING WHEN KNEE RANGE OF MOTION IS LIMITED

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Introduction: Adaptability is a key aspect of gait as it allows flexible coordination of the various joints so that the same movement outcome can be achieved with different contributions of the joints [1]. In the lower limb, this is facilitated due to a relationship that exists between the knee and hip joints [2] where 2 jointed muscles have opposing actions at adjacent joints. In obstacle clearance tasks, active knee flexion causes passive hip flexion during clearance [3.] As the execution of multiarticular tasks can utilize a variety of contributions of involved joints, this flexibility permits the alteration of joint contributions to permit safe ambulation throughout a series of environments and conditions. The aim of this study is to decrease knee range of motion (ROM) and quantify the compensatory adaptations that occur at the hip and ankle joints by examining joint moments and powers.

Methods: Eight subjects (4 female, 23.0 ± 1.8 years, 1.7 ± 0.1 m tall, 69.6 ± 15.0 kg) with no history of knee or hip injuries completed over-ground walking and obstacle clearance trials (18 cm and 6 cm). Trials were performed while unbraced and while wearing a ligament stabilizing knee brace on their right side which restricted flexion to 30°, 50°, and 70° respectively. Ground reaction forces were measured from four embedded force plates and lower limb kinematics were collected at 60 Hz using 6 banks of Optotrak sensors (NDI, Waterloo, ON) and 5 rigid bodies affixed to the pelvis, right thigh and shank, and both feet. The unbraced block was performed first to establish a baseline, followed by three randomized blocks for the brace conditions. These blocks consisted of three randomized conditions (unobstructed walking, 18cm obstacle, 6cm obstacle) which each had five trials.

Results: Decrements in mechanical work at the knee during the K5 burst that appears only during obstacle clearance was a direct result of restricting knee ROM. In order to maintain successful toe clearance, increases were seen in the mechanical work during hip pull off (H3). The largest changes were seen with 30° flexion blocks that reduced the knee ROM the greatest. Pending individual differences, larger knee flexion blocks may or may not impinge movement with level walking, low or high obstacle trials.

Discussion and Conclusions: Participants were able to successfully perform level walking and obstacle clearance during all conditions. The knee brace was able to restrict motion to 30°, 50°, and 70° and decrease the amount of joint power that could be delivered at the knee joint. Successful completion of level and obstructed walking required compensations at adjacent joints.

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CAN INERTIAL MEASUREMENT UNITS ACCURATELY QUANTIFY LUMBAR POSTURE IN PROLONGED TASKS?

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Introduction: Inertial Measurement Units (IMUs) can quantify 3D postures effectively, but their use has been limited to short duration tasks and they require extensive mathematical processing to limit drift errors[1]. The purpose of this study was to determine if IMUs can measure 3D postures over longer periods of time without the need for extensive mathematical corrections.

Methods: Nineteen participants (8 male, 11 female) completed 30-minutes of a static task (typing) and 30-minutes of a dynamic task (sorting). Each task was divided into 15-minutes of standing and 15-minutes of sitting in an office chair with no backrest. Lumbar flexion, lateral bend and axial twist angles were measured simultaneously by an established optoelectronic system (Optotrak Certus) and by IMUs (IDG500/ADXL335, SparkFun) consisting of tri-axial accelerometers and bi-axial gyroscopes. Accelerometers were treated as in [2], gyroscopes were calibrated to a fixed angle and drift was corrected through linear detrending. RMS error and Pearson product moment correlations were used to compare the outputs of the two systems.

Results: The RMS errors were greater for flexion than for lateral bend and axial twist ($p<0.0001$) and greater in standing than sitting ($p<0.0001$; Table 1). There was an offset between measurement system's mean angles in flexion (mean=12.5°, SD=13.9°) but not in lateral bend (mean=2.1°, SD=5.4°) or axial twist (mean = 1.9°, SD=4.7°). While all correlations were found to be significant ($p<0.001$), those for axial twist were low (typing) and moderate (sorting) while flexion and lateral bend showed strong agreement ($p<0.0001$; Table 1). Both the IMU and Optotrak systems were able to differentiate the changes in flexion between sitting and standing ($p<0.0001$), but only the optoelectronic system was able to distinguish the twisting requirements of the two tasks (IMU p=0.42, Optotrak p=0.0095).

Discussion and Conclusions: The strong correlations in flexion and lateral bend suggest the two systems tracked together, though a bias was present. Although the RMS errors were low in axial twist, the IMUs only accounted for 6% to 47% of the variance measured by the Optotrak system. Also considering the IMUs ability to distinguish flexion but not twisting requirements, extensive mathematical corrections are needed to use IMUs in prolonged axial rotation exposures.

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Table 1 - Root mean square errors and correlations between IMU and Optotrak systems in seated and standing sorting and typing tasks.

		Flexion				Lateral Bend				Axial Twist			
		Sit /Sort	*Stand /Sort*	*Sit /Type*	*Stand /Type*	*Sit /Sort*	*Stand /Sort*	*Sit /Type*	*Stand /Type*	*Sit /Sort*	*Stand /Sort*	*Sit /Type*	*Stand /Type*
RMS Error*	*Mean*	113.8 B	211.6 A	135.9 B	212.0 A	36.8 C	46.5 C	33.0 C	45.4 C	26.1 C	30.8 C	25.8 C	33.8 C
	SD	54.8	99.3	81.0	90.6	19.5	33.4	14.8	28.7	10.9	16.1	12.8	31.7
PPMC	*Mean*	0.981	0.922	0.953	0.930	0.852	0.839	0.819	0.871	0.682	0.595	0.375	0.241
	SD	0.017	0.077	0.063	0.093	0.405	0.350	0.421	0.153	0.142	0.239	0.180	0.241

***RMS Errors are expressed as a percentage of the range of angles measured within a condition.**

MODULATION OF PEAK FORCE AND PEAK PRESSURE DURING A SIMULATED HIP IMPACT

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Introduction: It has previously been proposed that soft tissue might play a role in absorbing energy from a lateral pelvis release[1]. A recent study investigated this hypothesis by studying the effect of body mass index (BMI) on energy absorption during a lateral pelvis impact[2]. Yet, the effect of local muscle activation on the physical properties of local tissue and consequently the effect on the magnitude and distribution of pressure has yet to be studied. Understanding the effect of local muscle activation on the pressure sustained during impact could reveal insightful information for injury prevention during lateral falls.

Aim: To determine the effects of muscle contraction on the magnitude and distribution of pressure and force of impact during a lateral pelvis release with an end goal of determining the viability of trained or induced muscle contractions during sideways falls to prevent injury in the form of a femoral fracture.

Methods: A total of 30 young participants will be recruited for the study. Surface Electromyography (EMG) will placed on the right and left vastus lateralis (VL), external oblique, lumbar erector spinae and gluteus medius (GM) muscles to determine activation state of the muscles, using an 8 channel Bortec system (Bortec Biomedical, Calgary, AB). Maximum voluntary contractions (MVC) will be performed for each muscle, followed by three practice trials in which participants will attempt to contract their right and left GM to 25% MVC and VL to 15% MVC. Participants will undergo four lateral pelvis release trials from each drop height of 0 cm, 1.5 cm and 5 cm for a total of 12 trials. Two of the four trialss per drop height will require participants to contract both their right and left GM to 25% and VL to 15%, as previously practiced, while being instructed to relax completely for the other two trials. Peak impact force will be collected with an AMTI OR6-7-2000 force plate (AMTI, Waterdown, MA), sampled at 1500 Hz while pressure will be collected with an RSscan high speed 0.5m Hi-End footscan® system (Rsscan International, Olen, Belgium), sampled at 500 Hz. Prior to beginning the lateral pelvis release experiments, the surface EMG on the left side will be removed to avoid any interference with the pressure measurements.

Expected Results: We hypothesize that the changes in the physical properties of the muscles due to muscle activation will result in the following changes: 1. we expect to see a larger surface area making contact with the pressure plate during the contracted trials, 2. because of this, we expect to see greater pressure distribution during the contracted trials, resulting in lower peak pressure and 3. the increased surface area will result in greater potential for energy absorption and therefore lower peak force.

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Influence of Tablet or Computer and Work Surface Angle on Upper Limb Kinematics

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Office workstation configuration changes are used in ergonomic interventions to reduce worker discomfort and injury risk. An emerging trend is the use of sit-stand and/or tablet workstations to increase worker mobility. These workstations may have negative effects on upper limb joints by increasing time in more physically demanding postures[1]. This investigation tested the effect of work surface angle and tablet or computer input hardware on upper limb kinematics when using a hybrid standing workstation (Focal Upright Furniture, New York, USA).

Fourteen healthy participants (age 22.4(0.6) years; mass 70.8(13.4) kg; height 1.73(0.09) m) participated in this study. Three-dimensional kinematic data for the right upper limb were obtained using an active motion analysis system (Optotrak Certus, NDI, Waterloo, CAN) sampled at 32 Hz. Participants were exposed to four workstation configurations in a crossover design with two work surface conditions (horizontal and sloped 15º) and two hardware types (computer and tablet): horizontal-computer (HC); horizontal-tablet (HT); sloped-computer (SC); and sloped-tablet (ST). In each configuration, participants completed three tasks: reading (Read); electronic form-filling (Form); and writing e-mails (Mail). Three-dimensional shoulder, elbow and wrist angles were calculated and amplitude probability distribution functions (APDF) were used to determine the median posture (50^{th} percentile) for each condition.

A main effect of workstation was found for: shoulder abduction and flexion; elbow flexion; and wrist flexion. The ST workstation increased shoulder and elbow flexion by 10.7°(1.2) and 17.3º(5.2) respectively when compared to the HC. A main effect of task existed for: shoulder abduction; elbow flexion; and wrist abduction and pronation. Elbow flexion increased by 12.5º(2.8) and 19.8º(5.2) in Form and Mail when compared to Read. Wrist abduction increased 31.2º(5.6) in Form compared to Mail. Wrist pronation increased 9.6º(3.4) and decreased 21.6º(5.5) during Form and Mail when compared to Read.

Overall, the horizontal computer workstation had the lowest joint flexion values whereas the horizontal tablet conditions had the lowest abduction and pronation angles. The Mail task corresponded to the lowest flexion angles, whereas the lowest abduction and pronation angles occurred during Read. It is recommended that the HC workstation be used for dedicated typing or reading and HT used for intermittent typing tasks. Although sloped workstations increased upper limb joint angles, future work should assess the influence on neck and trunk postures. As well, future work on muscular activation comparing the tested workstation configurations would provide additional insight to the physical demands in these settings.

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MUSCLE STRUCTURAL AND MECHANICAL REMODELLING IN RESPONSE TO LUMBAR FACET JOINT DEGENERATION IN THE RAT

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Introduction: There is a well-known association between muscle function or dysfunction and low back pain [1,2]. However, there is still little information regarding muscle remodelling following injury. In a recent study, Brown et al. [3] induced disc degeneration in the rabbit and measured increased passive muscle stiffness in the lumbar multifidus after three months. This was one of the first studies to demonstrate muscle remodelling in response to spine injury. A novel surgical technique has recently been developed, using brief direct mechanical compression of the lumbar facet joint of the rat, which initiates degeneration of the facet and hypersensitivity of the spinal cord similar to findings in human lumbar facet disease [4].

Aim: To determine whether multifidus muscle mechanical properties are altered by muscle remodelling following facet joint compression.

Methods: L5/L6 facet joint compression (n=10) and sham facet joint exposure (n=10) surgeries will be performed on the right side of male Sprague Dawley rats. A third group (n=10) will be a non-surgical control. One month post-operation, rats will be euthanized and multifidus muscle biopsies will be taken from L2/L3 and L5/L6 levels contralateral to the surgical procedures. Mechanical testing, in relaxing solution to ensure passive state of muscle, will be performed on single muscle fibres and bundles of muscle fibres (within surrounding connective tissue). Samples will be tied to a high-speed motor and micro-level force transducer. Samples will be lengthened until they begin resisting stretching (slack length) and all further testing will be measured from this point. Laser diffraction will be used to measure sarcomere length. Samples will be stretched in ~0.25 µm/sarcomere increments with 180 s between stretches to allow for stretch relaxation. Single fibre and fibre bundle elastic modulus will be compared between levels and conditions to investigate site specific remodelling due to injury. Facet joints will also be harvested bilaterally and examined for the presence of degeneration by histological analyses.

Expected Results: The operated facet joint will demonstrate signs of degeneration such as decreased proteoglycan content and cartilage degeneration compared to the contralateral facets. The contralateral facet will have no statistical differences compared to the sham and non-operative controls. It is expected that multifidus muscle will demonstrate increased passive stiffness bilaterally, in order to compensate for the degenerated facet joint. Muscle fibre bundles are expected to have a greater increase in elastic modulus compared to single fibres, as the connective tissue is the most likely site of muscle remodelling.

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IS THERE A RELATIONSHIP BETWEEN PATELLAR TENDON STRESS-TIME HISTORIES AND TRUNK AND LOWER EXTREMITY SAGITTAL PLANE KINEMATICS DURING A HORIZONTAL AND VERTICAL DECELERATION TASK?

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Introduction: Patellar tendinopathy (PT) is a clinical condition characterized by activity-related anterior knee pain. Commonly experienced by basketball and volleyball players, and at a higher rate in men than women, PT has been linked with decreased functional capacity, chronic pain, lost playing time and early retirement. Although the specific mechanisms of the condition are not clearly understood, it has been suggested that an individual's landing mechanics may influence his or her risk by modifying the patellar tendon loads[1]. Therefore, attempts to better understand the relationship between athletes' jump mechanics and their tendon loading may assist to establish objective criteria with which to predict the risk of developing future PT.

Aim: The aim of the proposed study is to examine the relationship between trunk and lower extremity kinematics, and patellar tendon loading during two deceleration tasks.

Methods: Forty university volleyball and basketball players (20 men and 20 women) will perform a vertical and a horizontal bilateral deceleration task. In the vertical task, athletes will step off of a 30 cm platform and immediately perform a maximum vertical jump immediately after contacting the force plate. In the horizontal task, athletes will perform a broad jump to a target located at 75% of their height. Whole-body kinematics will be recorded together with ground reaction force data, and a "bottom-up" inverse dynamics analysis will be performed to calculate the net joint knee moment. A single-equivalent muscle model will be used to quantify patellar tendon force by dividing the net knee joint moment by an estimated patellar tendon moment arm. The patellar tendon force will then be divided by an estimated cross sectional area to yield a patellar tendon stress. Multivariate regression analyses will be conducted separately for each joint to examine whether and to what degree trunk, hip, knee, and ankle range-of-motion, and instantaneous and average velocities, are related to characteristics of patellar stress-time histories (i.e., peak, impulse, and rate of stress development) during landing.

Expected Results: Athletes who exhibit higher trunk[1] and knee flexion velocities, smaller trunk and hip range-of-motion, and increased ankle dorsiflexion velocity[1] when landing, are expected to impose higher demands on their patellar tendon. It is the intention to determine if a movement pattern exists that is associated with higher patellar tendon loads, and to ultimately use these findings to develop PT risk screening procedures for basketball and volleyball athletes.

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ESTIMATION OF SPINAL LOADING USING INERTIAL MOTION SENSORS AND 3D LOADING MODEL

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Introduction: Approximately three in four Canadians working in the manual material handling industry suffers from back pain due to injury during their career[1]. Spinal loading during manual material handling, a cause of many injuries, is difficult to evaluate in the workplace with our current technology. There are systems that can record the required measurements, but they are not appropriate for a variety of reasons. Motion capture systems are expensive and difficult to use outside the lab. Systems like the Industrial Lumbar Motion Monitor (iLMM3) are expensive and the METS system does not measure the upper body, rendering the measurements incomplete. On the other hand, inertial motion sensors (IMS) are portable and accessible, making the transition from the lab to the field a possibility. The data collected from IMS can be used in combination with a simplified loading model to assess spinal loading in the workplace.

Aim: This study will evaluate the use of IMUs to estimate spinal loading. IMU data will drive a simplified upper-body model and the accuracy of the predicted spinal loads will be evaluated.

Methods: The performance of an occupational lifting task will be measured and recorded in the workplace. Once measured, a mockup of the task will be created in the Biomechanics and Ergonomics lab at Queen’s University. Workers familiar with the task as well as control subjects will be invited to perform the task in the laboratory. Motion capture system, Qualisys (Göteborg, Sweden), as well as body mounted IMS sensors placed on the trunk, upper arm and forearm will track the lifting motion. Both sets of measures will be used in an upper limb 3D link-segment model to estimate spinal loading. Analysis will determine the degree of difference in the estimated spinal loads between the lab-based and field-based recording systems and determine which measures are responsible for the differences.

Expected Results: It is expected that the spinal loads estimated using the IMU sensors will correlate with those using the Qualisys motion capture data. In addition, we will have information on which measurements are absolutely required to accurately estimate spinal loads and which measures can be modeled or estimate and which can be omitted without adverse effects on the outcome.

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EVALUATION OF BIOMECHANICAL AND NEUROMUSCULAR EFFECTS OF PROPHYLACTIC KNEE BRACE USE FOLLOWING EXERCISE

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Introduction: Injuries to the anterior cruciate ligament (ACL) are a common musculoskeletal injury affecting short term function and increasing long term risk of developing knee osteoarthritis[1,2]. The use of a prophylactic knee brace has been proposed as an adjunct in order to prevent ACL injuries in an athletic population with confounding results [3]. The biomechanical and neuromuscular effects of knee brace use following exercise is unknown. The purpose of this investigation was to identify biomechanical and neuromuscular effects associated with prophylactic knee brace wear following standardized exercise and whether documented effects lasted up to 30-minutes after the removal of the brace.

Methods: Twelve healthy university-aged recreationally active females volunteered for this study. Participants were required to come into the lab for two test sessions, 7-days apart (one session with no brace and an intervention session with brace wear during exercise). Participants were outfitted with a bi-lateral leg and trunk Optotrak markers (Optotrak Certus, Northern Digital Inc., Waterloo, ON) and electromyography (EMG) on relevant lower limb musculature (Bortec Biomedical Ltd, Calgary, AB). Single-leg landings on a force plate (AMTI, Waterdown, MA) from a 0.36 metre platform at five points through the intervention were completed: upon instrumentation, after brace application, after 30-minutes of jogging (1.2-1.9 m/s) exercise, after brace removal, and 30-minutes post-brace removal. Force plate, joint angle, joint moment, and EMG variables were extracted from the dataset. Main effects of brace wear were assessed using analysis of variance (ANOVA) and equivalency testing (considering ±10% of unbraced values as clinically equivalent).

Results: ANOVA revealed minimal effects of the brace on all dependent variables with no significant main effect of brace for majority of variables. Equivalency testing revealed that mean differences for the variables tested (Table 1) demonstrated a time-dependent outcome, with equivalency present depending on time period.

Discussion and Conclusions: Difference tests (ANOVA) indicate that the prophylactic knee brace used had a minimal effect on biomechanical and neuromuscular variables following and 30-minutes post exercise for recreationally active, healthy female participants.

References:
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<u>Table 1:</u> Equivalency tests for a subset of variables considered in the literature as differentiating those at high-risk of ACL injury. -/+ signs indicate directionality of mean differences beyond the ±10% reference bounds, and *Equiv.* signs indicate equivalency of means between unbraced and braced conditions.

	TIME 1	TIME 2	TIME 3	TIME 4	TIME 5
Frontal knee angle at ground contact	-	-	+	+	+
Hamstrings onset	Equiv.	Equiv.	Equiv.	-	-
Sagittal knee ROM	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.
Rate of loading	-	-	Equiv.	Equiv.	Equiv.

INVESTIGATING THE RELATIONSHIP BETWEEN HIP POSITION AND LUMBAR SPINE RANGE OF MOTION

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Introduction: The relationship between hip position and lumbar spine range of motion (ROM) is not yet well understood. One possible causative factor for individuals adopting excessive lumbar flexion is limited hip ROM. Excessive lumbar flexion increases strain and loading on passive and active spinal tissues, which can result in low back pain. The lumbar spine and hips are connected via the pelvis; therefore limited hip flexion can cause greater lumbar flexion through pelvic posterior tilt during flexion of the trunk and related postures (such as lifting or squatting)[1]. Increasing ROM through the hips can potentially decrease the need for flexion at the lumbar spine, thus decreasing the demand on the spine and associated musculature.

Aim: Determine the relationship between various hip positions and the ROM exhibited in the lumbar spine. Findings from this study have the potential to guide hip and low back movement strategies for patients with flexion-related low back pain.

Methods: Participants will be recruited from a university population and be required to have no current or history of hip or back pain or associated injuries. Participants will need to exhibit at least 120° of active hip flexion, which is the minimum degree of flexion for healthy ROM stated in previous literature[2]. An active marker motion capture system and associated software (Optotrak™ Northern Digital Inc., Ontario, Canada) will be used to record body segment and joint movement. Markers will be placed in rigid body clusters on the lumbar spine at vertebral levels T12, S1 and on the lateral aspect of the thigh. Electromyography (EMG) will be recorded to measure muscle activity of the lumbar erector spinae, rectus abdominis, external oblique, and internal oblique (AMT-8™ Bortec Biomedical Ltd., Alberta, Canada). Participants will perform full trunk flexion and extension, trunk lateral bend and trunk axial twist in each of the following hip positions: neutral stance, abducted, externally rotated, internally rotated, abducted and externally rotated and abducted and internally rotated. Participants will also perform various dynamic tasks (e.g. symmetrically and asymmetrically lifting a box from the floor) in the same hip positions, with no coaching on movement techniques. The dependent variables (3D lumbar spine motion, EMG amplitudes) will be compared between all hip positions within each task.

Expected Results: The least amount of lumbar spine range of motion during the dynamic tasks is expected to be observed when the hips are abducted and externally rotated. This position can allow greater movement through the hips, reducing the amount of movement required by the lumbar spine to complete the task. Due to the reduced lumbar spine flexion, the level of activation of the erector spinae muscles will be the least during abduction and external rotation during the lumbar spine ROM trials. The greatest amount of lumbar spine range of motion is expected to be observed when the hips are internally rotated during dynamic tasks. Internal rotation will severely limit the movement of the hip, resulting in greater movement about the lumbar spine to complete the task. Therefore, erector spinae activation levels are expected to be the greatest during internal rotation compared to all other lumbar spine ROM trials, due to the increased dependence on the lumbar spine for movement.

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EFFECTS OF TRAUMATIC BRAIN INJURY ON TOE CLEARANCE DURING OBSTACLE NEGOTIATION IN THE PRESENCE OF A VISUAL SCANNING TASK

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Introduction: In individuals with a Traumatic Brain Injury (TBI), dual-task paradigms have been employed to demonstrate their altered locomotor behaviour in response to physically- and attentionally-challenging environments. Through administering a cognitive task involving visual scanning and increasing the number of choices in walking trajectory with oncoming obstacles in the path, we seek to provide additional insight into the ability of individuals with TBI to navigate safely in everyday life situations. The overall goal of this research is develop new models of assessment that increase the challenge of locomotion, and thus, provide a greater ability to evaluate the trajectory of recovery following TBIs.

Methods: A choice reaction paradigm was incorporated into a typical dual-task protocol. The physical component consisted of walking along one of three possible paths in a gait laboratory: 1) simple straight-line walking; 2) circumventing a tall cylindrical obstacle on either side; and 3) either avoiding or stepping over a wide raised platform. Auditory instructions, indicating which path to follow, were provided 1-metre before each point of path divergence. The concurrent cognitive component consisted of a visual scanning task in which participants read aloud the letter that appeared in a moving circle ('A' or 'B') that was shifting in position on a screen every 1.5 seconds. A Vicon MX Motion Capture System (Vicon Inc., CO, USA) was used to measure behavioural characteristics (e.g. obstacle clearance). A Logitech H600 wireless headset (Logitech, CA, USA) was used to record cognitive task performance.

Results: Lead toe clearance observed during stepping over the platform, with and without a dual task, is presented in Figure 1 for six participants (n=6), 3 with TBIs and 3 able-bodied controls. The preliminary findings suggest that, in general, the dual task caused a reduction in obstacle clearance in both groups, and that the dual-task costs were greater for the TBI group.

Discussion and Conclusions: Further work will be focused on increasing the number of outcome measures, trials, and participants processed in order to determine if the effects observed are statistically significant and to reveal further relationships in the data. The influence of potentially confounding factors (e.g subject height or disease severity) will also be considered. Going forward, this work will be used as a foundation on which to assess individuals who use assistive aids and have more severe TBIs.

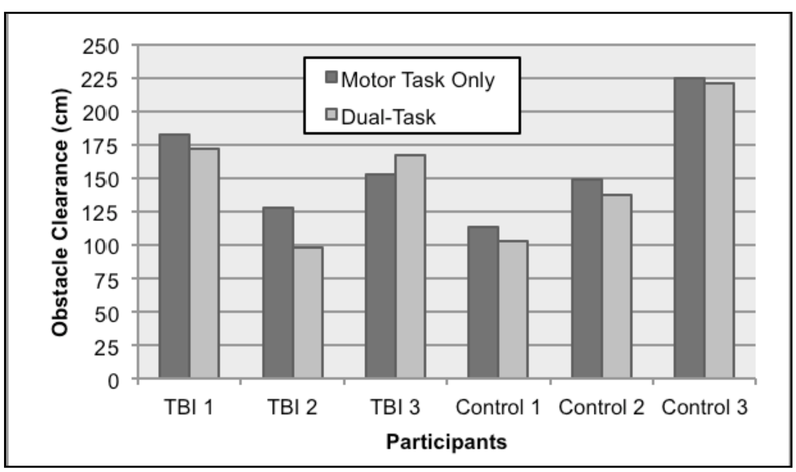

Figure 1: Effect of Dual-Tasking on Lead Toe Clearance during Stepping Over and Obstacle in TBI and Control Participants

THE EFFECT OF DUAL-TASKING ON COMPENSATORY ARM RESPONSES IN YOUNG AND OLDER ADULTS

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Introduction: Balance recovery strategies that occur in response to an external perturbation are often believed to be controlled through reflexive pathways. However, research incorporating a dual-task paradigm has shown that when a cognitive task is performed at the same time as a balance task, lower limb muscle responses to a loss of balance become smaller [1]. Since dual-tasking decreases the availability of cognitive or cortical resources for balance control, these results suggest that cortical input is required to produce balance recovery strategies involving the lower limbs. Despite this knowledge, studies have not yet examined whether a dual-tasking paradigm can also be used to demonstrate that upper limb balance recovery strategies (i.e., compensatory arm response) require cortical resources. If this can be shown, this would provide a relatively simple method to assess whether ageing alters the cortical requirements for generating a compensatory arm response. This is important because older adults are more reliant on, but slower to initiate a compensatory arm response for balance recovery [2].

Aim: The aim of this study is to determine whether the ability of young and older adults to generate a compensatory arm response is affected by the performance of a concurrent cognitive task.

Methods: Twenty young adults (18-30 y of age) and 20 older adults (>65 y of age) will begin each trial by performing a verbal subtraction task at one of two difficulty levels (i.e., subtracting by 2's or 7's). At a random time during the counting task, participants will experience a horizontal support surface translation in either the forward or backward direction. In response to each surface translation, participants will be required to recover their balance as quickly as possible without stepping. The effects of dual-tasking on the generation of compensatory arm responses will be determined from electromyographic (EMG) onset latencies and amplitudes of the shoulder muscles, as well as three-dimensional kinematics of the upper limbs.

Expected Results: It is hypothesized that slower and smaller compensatory arm responses will be observed during the more difficult (subtracting by 7's) compared to the easier (subtracting by 2's) dual-task condition. Further, it is expected that dual-tasking will have a greater effect on the ability to generate a compensatory arm response in older compared to young adults. These results would suggest that cortical resources are required to produce a compensatory arm response and that these cortical requirements increase with age.

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TWO DIFFERENT METHODS OF EVOKING BALANCE LOSS IN YOUNG ADULTS IN DYNAMIC CONDITONS: A PILOT STUDY

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Introduction: Falls are a leading cause of injury, disability and death in Canada. Handrails are common walkway installations that, when well-designed, can significantly increase a person's ability to recover from balance loss and avoid a fall, by allowing the user to quickly grasp the rail and then generate the high forces and torques needed to stabilise his/her centre of mass (COM) [1]. Despite the widespread use of handrails in the built environment, our understanding of the consequences to balance recovery when a handrail is too high, low, large or small is limited. An issue in studying how key handrail design features influence balance recovery lies in safely and consistently disrupting a person's balance to the extent that (s)he is reliant on the handrail to recover from balance loss during ongoing gait, rather than on compensatory stepping reactions. Translational walking-surface perturbations (e.g. [2]) can be used to disrupt balance – the challenge is to deliver these perturbations with kinematic profiles that induce sufficient balance loss, while limiting the artefact of the perturbation on the kinematic and kinetic data collected by instrumentation on the platform.

Aim: This study aims to investigate how two different methods of disrupting balance using translational platform perturbations influence 1) balance loss and recovery in younger adults; and 2) error in the data collection instrumentation caused by the platform perturbation.

Methods: Data collection took place in the Challenging Environment Assessment Laboratory at Toronto Rehab, with a robotic platform that can deliver translational perturbation. Eleven young adults (23-29y) were asked to walk along the platform several times beside a handrail. Two different translational perturbation conditions were tested during both level ground walking and ramp descent: a high-velocity perturbation profile with high-traction ('normal') footwear, and a lower-velocity perturbation profile with reduced-traction ('slippery') footwear. These unexpected perturbations were used to induce balance loss and evoke a reach-to-grasp reaction. Motion capture cameras on the platform walls collected kinematic data; load cells on the handrail posts collected kinetic data; and surface electromyography on the medial deltoids was used to approximate reach-to-grasp muscular onset latencies. A 11-link-segment model (trunk, wrists, upper/lower limbs) will be used to approximate COM displacement and reach-to-grasp kinematics.

Expected Results: Most participants have reported that balance recovery is more challenging in the 'slippery' condition, despite the lower-velocity perturbation profile compared to the 'normal' condition. We expect that the error in the kinetic and kinematic data will be lower in the 'slippery' condition. We also expect that downward COM displacement will be greater and that muscular reaction onset latency will be slower in the 'slippery' condition.

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Ontario Biomechanics Conference Podium Presentations
14th-16th March 2014

Podium Sessions A: Saturday 15th March 8:30am - 9:30am

Podium Session	Presenter	Title
A: Tissue Mechanics and Injury Saturday 15th March 8:30am – 9:30am	Danielle Stewart	The tensile properties of single lamella from lamb annulus fibrosus
	Kathleen MacLean	Reliability of white light interferometry for assessing bone surface morphology
	Kayla Fewster	Exploring the regional response of the intervertebral disc under postural varying loads
	Lauren Monaco	Comparative analysis of biomechanical and anatomical properties of the intervertebral disc from three model species
	Mamiko Noguchi	Intradiscal pressure response during intervertebral disc herniation
	Thomas Karakolis	Implications of biaxial tensile testing for modeling the mechanical behaviour of the annulus fibrosis

THE TENSILE PROPERTIES OF SINGLE LAMELLA FROM LAMB ANNULUS FIBROSOUS

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Introduction: Animal models such as ovine and porcine intervertebral disc (IVD) have been used to model the adult human IVD in respect to anatomical shape [1], mechanical properties [2] and collagen content [3] in an effort to better understand the load bearing function of the IVD. There is little research however, surrounding the use of lamb IVD as a comparative model to the human IVD. The present study reviewed the biomechanical stress/strain relationship of the intra-lamellar matrix of the annulus fibrosus (AF) in the posterior and anterior regions of lumbar IVD of lambs.

Methods: Twenty-one single lamella samples were garnered from five lumbar lamb spines using a stereoscope (Leica Microsystems, Wetzlar, Germany). Specimens were considered lamb if they were <12 months old. Samples were mounted onto the Biotester 5000 (CellScale, Waterloo, Ontario) perpendicular to the orientation of collagen fibers. Tissues were preloaded to 10% strain for three intervals at a rate of 1% strain/sec. Tissues were then strained to failure at a rate of 2%/sec. The stress (MPa) and strain (%) at the end of the toe region, initial failure, and ultimate failure were recorded. Young's Modulus was also determined for each tissue by calculating the slope of the stress-strain curve in the linear elastic region. A one-way ANOVA based on location (anterior versus posterior) was used to determine the statistical significance of each dependent variable; an alpha of 0.05 was considered significant.

Results: Biomechanical test results identified significant differences in stress at the end of the toe region ($p = 0.033$) and at initial failure ($p = 0.042$) as a function of sample location. The stress at the end of the toe region in the posterior region was found to be over six times higher than that in the anterior region, and the stress at initial failure for posterior tissues was found to be over 2.5 times higher as compared to the anterior regions.

Discussion and Conclusions: The intra-lamellar matrix of annulus fibrosus in lamb demonstrates regional variation in mechanical properties, suggesting that the posterior disc can resist higher stresses prior to failure. This may be a protective mechanism against herniation development in the posterior region. Current work in our lab is comparing these findings to that of adult sheep to understand the developmental changes in the IVD in this particular model.

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RELIABILITY OF WHITE LIGHT INTERFEROMETRY FOR ASSESSING BONE SURFACE MORPHOLOGY

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Introduction: Bone morphological properties, including bone shape, size, composition and boney element orientation, relate to functional abilities and limitations. Indeed, it enables anthropological morphological comparisons to understand evolutionary adaptations to boney configuration. Although there are many methods of imaging bone surfaces, none are universally efficient, accurate or cost-effective [1]. One method for measuring surface morphology is White Light Interferometry (WLI), an optical method that measures surface heights on three-dimensional structures. This technology has been used widely, including assessing cartilage morphology [1] and osseointegration of titanium implants [2], but minimally in bone surface analysis. The purpose of this study was to assess the test-retest reliablilty of WLI for imaging human humeri to extract humeral torsion angle (Figure 1), a feature of interest in physical anthropology due to its supposed functional meaningfulness.

Methods: A single StarCam™ FW (VX Technologies Inc) white light scanner and a standardized protocol involving eight humeral scan positions were used to scan five cadaveric humeri during four separate scan sessions. Scans (8) from each session were used to reconstruct a three-dimensional humerus in Geomagic Studio Software (3D Systems Corp.). Each humeral image was imported into Matlab where a humeral torsion angle could be extrapolated. A two-way ANOVA determined the test-retest reliability of humeral torsion angle as measured by WLI. A second two-way ANOVA tested intra-rater reliability in measuring humeral torsion.

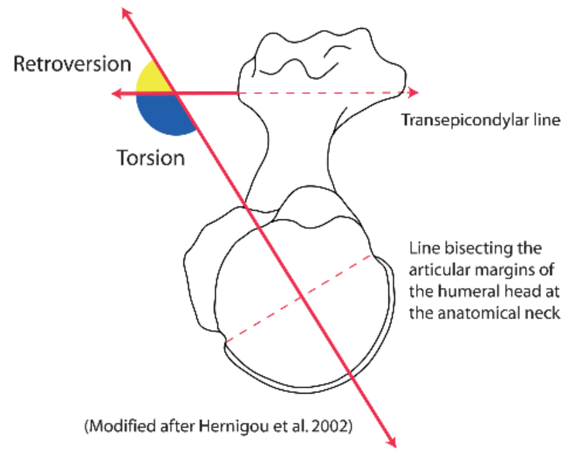

Figure 1: Humeral Torsion is measured as the angle between the lines created by the articulating surface of the humeral head and the transepicondylar line [3]

Results: Humeral torsion values ranged from 148-164°. There was no significant difference in test-retest reliability of humeral torsion angle ($p=0.561$). There was no significant difference in humeral torsion between measurement trials for any bone specimen ($p=0.747$).

Discussion: Results suggest that WLI is a reliable method for scanning human bones for quantitative morphological surface assessment. Although trial differences were not significant, the range of humeral torsion angles measured across scan session trials varied as much as 8° within bone specimen. Therefore, multiple scan sessions may be required to ensure that assessment of surface morphology is reliable.

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EXPLORING THE REGIONAL RESPONSE OF THE INTERVERTEBRAL DISC UNDER POSTURAL VARYING LOADS

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Introduction: Intervertebral disc (IVD) herniation generally occurs in the posterior region of the disc (Mobbs & Steel, 2007). A common outcome of disc herniation is a protrusion, which is characterized by a nuclear, annular, or nuclear/annular bulge (generally in the posterior direction), that extends into the spinal canal causing pain and discomfort. This research will look at the comparison between posterior and anterior radial displacement (*i.e.* bulging) of the intervertebral disc. This work needs to be performed as little research has investigated the effects of posture and load on radial displacement on the posterior side of the disc. This lack of research is because when the entire functional spinal unit is tested, the posterior side of the disc is covered by osseous tissue and ligaments, making it impossible to directly image. The primary objective of this work is to quantify the location and magnitude of anterior and posterior radial displacement in the IVD across loading conditions and postures, in order to better understand how the responses of the anterior portion of the IVD may be related to the posterior portion.

Methods: Eight cervical porcine units will be tested. A servo-hydraulic materials testing system will be used to apply flexion/extension motion as well as compressive loads to an intact functional spinal unit (FSU). A three-dimensional non-contact laser displacement sensor will be used to measure radial displacement (*i.e.* bulging) of the disc. Radial displacement will be compared across loads (0 N, 300 N, 600 N and 1200 N) and postures (neutral, flexion and extension). The anterior aspect of the 8 cervical units will be scanned during all conditions with the posterior elements intact. Then the posterior elements will be removed leaving a reduced FSU. Both the anterior and posterior sides of the disc will be scanned during all remaining conditions. There will be a total of 36 conditions (load x4, posture x3, scan location x3). The dependent measures will be the location and magnitude of radial displacement and will be computed from IVD surface profiles measured using the 3D laser displacement sensor.

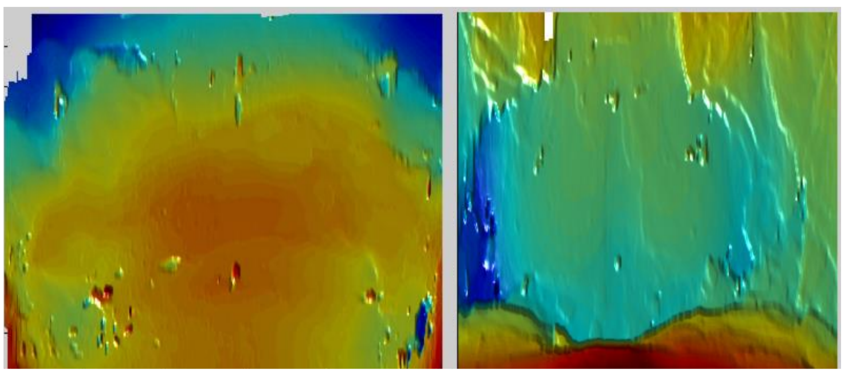

Figure 1: Anterior (left) and Posterior (right) surface profiles of radial displacement measured from the surface of an IVD using a 3D, non-contact laser.

Expected Results: It is hypothesized that a correlation between posterior and anterior radial displacement will occur. This may elucidate a link to measured radial displacement on the anterior side to make inferences on what is happening on the posterior side in intact structures.

Reference: Mobbs, R. J., & Steel, T. R. (2007). Migration of lumbar disc herniation: An unusual case. *Journal of Clinical Neuroscience*, *14*, 581-584.

COMPARATIVE ANALYSIS OF BIOMECHANICAL AND ANATOMICAL PROPERTIES OF THE INTERVERTEBRAL DISC FROM THREE MODEL SPECIES

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Introduction: The intervertebral disc (IVD) contributes to the weight-bearing and flexibility of the spine and is composed of two main components: the circumferential annulus fibrosus (AF) and centrally placed nucleus pulposus (NP). Each component can be distinguished by biomechanical properties, geometric and anatomical characteristics. Animal models are frequently used in place of human specimens due to availability of such specimens to study the progression of injury and/or disease. This project aimed to compare the geometry, hydration, and tensile properties of selected animal models: bovine (cow) tail, porcine (pig) lumbar, and ovine (sheep) lumbar IVDs (Figure 1).

Methods: Geometric measurements were obtained from frontal and sagittal x-ray images of full lumbar/tail spines from five bovine tail, five porcine and two ovine specimens. From these x-rays, IVD and vertebral height measurements were determined for each. IVD water content was determined by comparing wet versus dry weight of the IVDs after incubation for 24 hours at 65°C. Last, Young's modulus and failure stress and strain were determined for single lamellae of the AF pulled perpendicularly to their fibre orientation.

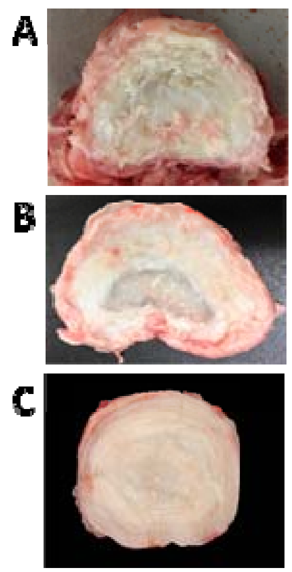

Figure 1. IVD of ovine lumbar (A), porcine lumbar (B), and bovine tail (C).

Results: The Young's modulus was significantly different between species ($p=0.005$), with bovine samples exhibiting the highest moduli and ovine exhibiting the lowest. Failure strains also differed between species ($p = 0.002$) with largest strains observed in ovine lamellae and lowest in bovine. No differences in failure stress were observed between the species ($p = 0.08$). Ratios of IVD:vertebral height revealed a statistically significant difference between species ($p <0.001$), where bovine had the largest ratio and ovine had the smallest. No significant differences in water content between species were observed ($p=0.22$).

Discussion and Conclusions: Bovine and ovine IVDs differ significantly in terms of their geometry and biomechanical properties, while porcine IVD properties seem to fall in between these models. The higher IVD:vertebral height exhibited by bovine tails is due to notably high IVDs in these tails. This differing geometry would likely affect functional spine unit (vertebrae and intervening IVD) mechanics rathe r than isolated IVD mechanics. Bovine lamellae were also found to be the stiffest of the models examined, which may be due to the fact they were excised from tails rather than lumbar IVDs, which are generally under different loads in vivo. By comparing these data with published human values, this study can aid in the selection of appropriate models to use when human specimens are not available.

INTRADISCAL PRESSURE RESPONSE DURING INTERVERTEBRAL DISC HERNIATION

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Introduction: Applying cyclic flexion-extension to healthy intervertebral discs has been shown to result in herniation [1]; however, it remains unclear whether the initiation of internal disc disruption can be objectively detected from empirical data. Since mechanical loading directly affects intradiscal pressure [2] and the stresses that the inner annulus fibrosus experiences, the mechanism that leads to disruption of the inner annulus fibrosus may be linked to changes in intradiscal pressure. Therefore, the purposes of this study were twofold: (i) to determine whether a bore-screw pressure sensor system can be used as an alternative pressure sensor minimizing annulus damage and (ii) to characterize time-varying changes in intradiscal pressure and vertebral joint mechanics using a cyclic flexion-extension (CFE) loading protocol previously shown to induce internal disc disruption [1].

Methods: Fourteen functional spine units (C34, C56) excised from the porcine cervical spinei were instrumented with a bore-screw pressure sensor system. A Gaeltec needle pressure sensor (8CTsshp; Medical Measurements Inc., Hackensack, NJ, USA) output was used as a criterion measure [3] to compare the values from the bore-screw pressure sensor. The CFE loading protocol consisted of 3600 cycles of flexion-extension applied at 1Hz with 1500 N of static compressive load. Three dependent measures were analyzed: (i) intradiscal pressure, (ii) sagittal-plane moment, and (iii) specimen height loss. For each flexion-extension cycle, average, maximum, minimum, and range values were identified.

Results: Step-wise and dynamic responses of the bore-screw pressure sensor system were comparable to the needle pressure sensor, as the maximum error projected at 1500 N was 0.30 MPa (< 10% error). In addition, implementing the bore-screw pressure sensor system did not change the specimen's neutral zone range ($p = 0.96$), height loss ($p = 0.12$), or peak moment increase ($p = 0.56$) following the CFE loading protocol compared to those results of intact specimens. Intradiscal pressure and specimen height decreased by 45% and 62%, respectively, and the peak moment increased by 102% following the loading protocol. All dependent measures exhibited significant changes after 300 cycles ($p < 0.05$). There were no sequential changes in pressure range after 2100 cycles whereas peak sagittal-plane moments and specimen height loss were significantly different throughout the entire CFE loading protocol. Twelve of the 14 specimens (85.7%) showed partial herniation; however, the magnitude of internal disc disruption was not significantly correlated to any of the dependent measures.

Conclusions: The bore-screw pressure sensor system can be used as an alternative method for characterizing intradiscal pressure changes without having to compromise the mechanical integrity of the annulus fibrosus (i.e. needle insertion is not required). Although pre/post changes in the pressure range were not predictive of the disruption magnitude, an increase in pressure range examined over time supports the premise that the inner annulus fibrosus failure mechanism is linked to fatigue.

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IMPLICATIONS OF BIAXIAL TENSILE TESTING FOR MODELING THE MECHANICAL BEHAVIOUR OF THE ANNULUS FIBROSIS

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Introduction: Intervertebral disc herniation involves failure of the annulus fibrosus caused by mechanical loading. Annulus mechanical loading can be studied through experimental testing or through the use of numerical models. The annulus is a composite lamellar structure and within each lamella there is thought to be a principle orientation of collagen fibres that resist tensile loading. Principal fiber orientation varies between layers of the annulus, when unloaded. Therefore, most numerical models are created with an annulus represented by adjacent lamellae, with each individual lamella having a slightly different material model in order to simulate the varying principal fiber orientation.

Methods: Eighty single and bi-layer porcine annulus tissue samples were tested (n=40 each). Samples were obtained from superficial and deep layers of the anterior and posterior C3/4 and C5/6 discs. Samples were approx. 4mm x 4mm. Average thickness was 0.13 ± 0.03mm (single-layer) and 0.36 ± 0.07mm (bi-layer). Biaxial tensile loading was conducted in a manner similar to that previously described [1] at a rate of 2% strain per second, to a peak of 20%. Preload and preconditioning were standardized. Temperature (30°C) and relative humidity (90%) were controlled. Using images captured during testing (5Hz), a virtual gauge region was defined and tracked in an effort to avoid artifact caused by the interface between testing system and specimen. Elastic moduli (EM) were compared using a two-way ANOVA, with location and number of layers treated as between factors.

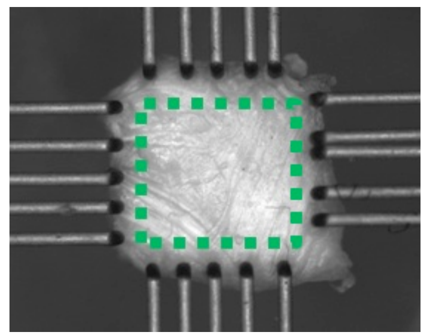

Figure 1: Annulus tissue sample in mechanical testing system. Dotted box represents virtual tracking points defining the gauge region.

Results: No significant interaction was found between location and layers (p=0.07). Average EM was 0.90 ± 0.71MPa (single) and 0.62 ± 0.42MPa (bi-layer). By location EM were: Anterior Superficial 0.53 ± 0.23 (single), 0.52 ± 0.38MPa (bi-layer); Anterior Deep 1.43 ± 0.80, 0.64 ± 0.19MPa; Posterior Superficial 0.55 ± 0.16, 0.54 ± 0.27MPa; Posterior Deep 1.10 ± 0.91, 0.77 ± 0.67MPa. Both location (p=0.003) and layer (p=0.02) were found to be significant factors.

Discussion and Conclusions: Bi-layer samples had a significantly lower EM than single layer. Given that the inter-lamellar component of a bi-layer is relatively thin, the elastic modulus was not expected to change. One possible explanation is that during tensile loading, collagen fibers of single and bi-layer samples re-arrange along the loading direction. In a single-layer, collagen may have a greater ability to re-arrange because they are not constrained by cross-link attachments between layers. The ability of collagen to re-arrange within each layer of the annulus may need to be considered in future disc models. *In vivo*, non-herniated disc's lamellae do not act as single unconstrained layers. Therefore, it may be more appropriate to use a bi-layer (or perhaps multi-layer) material model as the minimum functional unit to model the annulus.

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[1] Gregory DE and Callaghan JP (2011). A comparison of uniaxial and biaxial mechanical properties of the annulus fibrosus: a porcine model. *J Biomech Eng,* 133(2); 024503.

Ontario Biomechanics Conference Podium Presentations
14^{th}-16^{th} March 2014

Podium Sessions B: Saturday 15^{th} March 9:45am - 10:45am

Podium Session	Presenter	Title
B: Posture, Gait and Balance I Saturday 15^{th} March 9:45am – 10:45am	Amy Hackney	Is the critical point for aperture crossing adapted to the person-plus-object system?
	Chris Shaw	Adults with multiple sclerosis require balance- and proprioceptive- specific exercises to elicit continued improvement in static balance
	Glynnis Pardo	Energy adaptations of the trunk during transitions from level to inclined surfaces
	Helen Chong	Does a constrained ankle joint affect the flexion angles of the knee?
	Kaitlin Gallagher	The influence of lower limb position on the lumbar spine in three upright standing positions
	Tyler Weaver	Stooping and crouching postures: The applicability of the inverted pendulum model

IS THE CRITICAL POINT FOR APERTURE CORSSING ADAPTED TO THE PERSON-PLUS-OBJECT SYSTEM?

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[2] Department of Kinesiology and Physical Education, Wilfrid Laurier University, Waterloo, ON

Introduction: When passing through apertures, individuals scale their actions to their shoulder width and rotate their shoulders/avoid apertures 1.3x the shoulder width or smaller (Critical Point)[1,2,3]. Carrying objects wider than the body produces a person-plus-object system that individuals must account for in order to pass through apertures safely. The current study aimed to answer two questions: [1] Is the Critical Point scaled to the aperture width / person-plus-object width ratio (A/O) and [2] Is adaptation to the person-plus-object system instant or does it evolve with repeated exposure?

Methods: Participants (N=13, $\bar{x}$ = 23.3, ±1.1 years) walked at a self-selected pace along a 10m path and passed between or around two vertical poles placed halfway along the path. Participants performed the task with or without holding a serving tray that was either 1.2, 1.4 or 1.6 times wider than their shoulder width. The distance between the poles were scaled to be 1.0-1.6 times each participant's widest dimension (shoulder or tray) in increments of 0.2.

Results: All participants adapted to the person-plus-object system: the Critical Points in the final tray-carrying condition matched that of the control condition (no tray carried). However, the rate of adaptation differed among participants and two distinct adaptation rates emerged: fast and slow adapters. Fast adapters (n=7) maintained their Critical Point throughout the entire study (even when experiencing the tray for the first time) and approached and passed through the obstacles at the same velocity regardless of whether or not the tray was carried. On the other hand, slow adapters (n=6) increased their Critical Point, reduced their approach velocity and decreased their walking speed when carrying the tray compared to when the tray was not carried.

Conclusion: Although all participants adjust to the size of the object, individuals adapt at different rates. These results suggest that the relationship between the size of the person-plus-object and the size of the aperture that determines the passability of an aperture is updated differently across individuals. Individuals who can adjust their Critical Point to the size of the object instantly are likely to be more in-tune with this relationship between the body and aperture compared to those who adapt over time. *Slow adapters* appear to require time to experience the object through exploration before actions are scaled to its size[4].

References:

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ADULTS WITH MULTIPLE SCLEROSIS REQUIRE BALANCE- AND PROPRIOCEPTIVE-SPECIFIC EXERCISES TO ELICIT CONTINUED IMPROVEMENT IN STATIC BALANCE

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[2]Xanadu Health Club, Lakeshore, ON

Introduction: Multiple Sclerosis (MS) is a neurological disease that attacks the myelin sheath of axons within the CNS, affecting many sensory and motor systems including balance. Physical activity is known to aid in the improvement of balance, especially when balance- and proprioception-specific exercises are incorporated [1]. However, many studies that have used balance exercises in their intervention protocol were relatively short in duration for a training study (3-8 weeks) [1, 2]. The purpose of this study was to examine the effectiveness of a 16-week multi-faceted exercise program on static balance in adults diagnosed with MS.

Methods: Eight adults (mean age 51.3 years, range 42-65 years; 1 male) diagnosed with MS completed a 60 minute exercise program including cardiovascular, strength, balance and proprioception exercises, twice a week for 16 weeks at a local health club. Static balance was assessed at the beginning, middle, and end of the exercise program. Participants performed four 30-second quiet standing trials on a force platform (#OR6-7 2000, Advanced Mechanical Technologies Inc., Watertown, Massachusetts, U.S.A) – two with eyes closed (EC) and two with eyes open (EO). Anteroposterior and medio-lateral RMS displacements (RMSy and RMSx, respectively), RMS sway area, and range areas were compared ($p < 0.05$) between conditions (EO, EC) and across test sessions (baseline, mid-program, post-program).

Results: In the EC condition, there were significant improvements in RMSy ($p = 0.02$) from baseline to mid-program, and from baseline to post-program ($p = 0.04$), but not from mid- to post-program ($p = 0.39$). Significant main effects of condition were found for each dependent variable – in all cases, performance was significantly better during the EO trials compared to EC ($p < 0.05$).

Discussion: Improvements in RMSy in the EC condition but not in the EO condition suggests that improvements in neuromuscular proprioception were elicited through the exercise intervention. Since visual, vestibular and somatosensory systems all contribute to balance control [3], removing the visual component reveals the contributions of the other two sub-systems. During the second half of the program, participants progressed from balance-specific exercises in favour of more functional exercises that incorporated balance, but did not specifically train it. This may explain why no further significant improvements were elicited in the last half of the program. Specificity of training may be required to elicit continued improvement in the control of static balance in individuals with MS.

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ENERGY ADAPTATIONS OF THE TRUNK DURING TRANSITIONS FROM LEVEL TO INCLINED SURFACES

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Introduction: The transition from a level to an inclined surface presents a number of challenges to the locomotor control system and have been linked to more cautious gait [1,2]. Adaptations include increased base of support, decreased velocity[2], and elevated toe clearance[1]. Examinations of inclined walking have dealt primarily with steady state conditions and the transition from level to ramp walking has shown that gait patterns adapted for transition is distinct from steady state and graded to the incline[1,2]. Small but significant changes in trunk orientation occur in response to increased postural and propulsion demands associated with the change in orientation of the support surface[1] and have been hypothesized for the maintenance of the orientation of the head[3]. The purpose of the proposed research is to quantify the energy adaptations of the trunk during the transition from level to inclined walking. It was hypothesized that adaptations would directly grade to changes in inclination.

Methods: Peak kinetic and potential energy and their rates of increase were measured during the transition from level to four different inclined surfaces. Participants ascended a 3m walkway inclined at 3, 6, 9, & 12° from level. Motion was measured using 6 bank OPTOTRAK Certus Motion Capture System sampling at 128Hz. 25 Smart Markers arranged on 5 rigid bodies, tracked unilateral limb motion of the foot, shank, thigh, pelvis, and trunk A digitizing probe was used to create imaginary markers for the tracking of boney landmarks and characterization of limb motion. First contact with the ramp occurred in midstance. Data were filtered using a second order Butterworth filter with frequency cutoff 6Hz. Data were interpolated using a cubic spline, with maximum gap set to 10. An average stride for each inclination was computed by averaging of five strides. Each stride was time normalized from heel contact of step immediately preceding contact with ramp to the next consecutive heel contact of the same foot.

Results: No differences in potential energy were measured during changes in inclination. Timing of kinetic energy peak was consistent for each inclination. Kinetic energy peak increased with increases in grade, with largest peaks occurring at 12° inclination. Rate of kinetic energy increase, defined as the slope to peak kinetic energy, showed an increase with increases in grade.

Discussion and Conclusion: There would appear to be increased energy demands as ramp inclination increases, especially at the higher grades. Specific differences with slope demands will aid in the identification of slope transitions requiring substantive changes.

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[1] Prentice et al. (2004) *Gait* Posture 20: 255–265.
[2]Gottshall, J. S., et al. (2011) *Journal of Applied Biomechanics*, *27*(4), 355-361.
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DOES A CONSTRAINED ANKLE JOINT AFFECT THE FLEXION ANGLES OF THE KNEE?

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Introduction: Many occupations (e.g. roofing, tiling) and activities of daily living require high flexion postures (e.g. kneeling, squatting). Repetitive or prolonged periods of high flexion increase the risk of tibio-femoral joint damage, which makes required postures painful and difficult to complete [1]. The restriction of movement in the ankle and foot due to footwear, injury, or disease may alter the movement pattern of other joints (knee and hip) [2], which may increase the associated joint tissue damage risk. The objective of this study is to compare the knee and ankle angles in static deep flexion kneeling while barefoot (unshod condition) and wearing CSA-approved high ankle work boots, which include a rigid shank and steel toe-cap (shod condition).

Method: Eight asymptomatic male participants (age=23.9 (±1.6) years, mass=79/4 (±13.1) kg, and height=173.0 (±4.4) cm) completed this study. Bilateral kinematic data of the lower limb was recorded using a 6 bank 18 camera Optotrak 3020 and Certus system (Northern Digital Inc., Waterloo, ON) sampled at 64 Hz. Two predominant kneeling styles emerged, which resulted in 2 categories within the unshod condition: kneeling with the inferior aspect of the toes on the ground (bending at the forefoot-style 1) and plantar-flexion kneeling with the dorsal aspect of their foot contacting the ground (style 2). Only one style in the shod condition is relevant because the relatively inflexible ankle of the work boots requires participants to kneel in style 1. Only the left leg was analyzed due to approximately symmetrical nature of the activity. Kinematic data was subjected to a 2-way repeated measures ANOVA with $\alpha=0.05$.

Results: The symmetry of the activities was confirmed by the knee and ankle flexion angles in the unshod condition: left knee angle = 145.34° (±9.4°); right knee angle = 145.21° (±8.29°); left ankle angle=41.06° (±17.8°); right ankle angle=49.4° (±20.51°)). It was found that the angle of the knee and ankle were not significantly different when comparing within subject variability based on shod and unshod conditions, $p=0.708$.

Conclusion: Wearing boots did not alter the joint angles of the ankle or knee in comparison to unshod kneeling for a static posture; the sagittal plane kinematics show that this foot wear does not alter the movement in a way that would be expected to increase joint tissue damage. Future work will include analyzing the joint contact forces in the ankle and knee during deep flexion postures, analyzing the transitional phases in the stand-to-kneel sequence, and investigating different styles of footwear.

References:
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THE INFLUENCE OF LOWER LIMB POSITION ON THE LUMBAR SPINE IN THREE UPRIGHT STANDING POSITIONS

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Many standing aids marketed for the use during prolonged standing tasks work by changing the position of the lower limbs in order the change the angle of the lumbar spine[1], with many resulting in mild flexion of the lumbar spine[1,2]. We hypothesized that those susceptible to low back pain (LBP) development during prolonged standing may stand with a lumbar spine angle close to their extension end range of motion; therefore, an aid that brings lumbar spine angle away from the extension limit may be beneficial to this population. The purposes of this study were to determine (1) if prolonged standing pain developers (PDs) stand with a sagittal lumbar spine position closer to their extension end range compared to non-PDs, and (2) the impact of a standing aid that alters lower limb position on sagittal lumbar spine angle.

Methods: Seventeen subjects (eight females, nine males) had four sagittal lumbar spine radiographs taken during upright standing, standing on a sloped surface (16º decline), standing with one leg elevated (135º trunk-thigh angle), and maximum lumbar extension. All participants had their pain status' evaluated in a previous study using a visual analog scale during a two hour prolonged standing protocol. Eight non-PDs and nine PDs comprising the study sample. Measures of sagittal lumbar lordosis (LL), lumbosacral lordosis (LSL), and L1/2 and L5/S1 vertebral angles were calculated for each position and expressed relative to the maximum extension position.

Results: During upright standing, non-PDs had 3º more LSL flexion than PDs (Cohen's *d*=0.71, medium effect), but this was only significant at *p*=0.1318 (Figure 1). A main effect of POSTURE was also found for LSL (*p*=0.0003). For all participants, LSL was more flexed during the elevated condition versus upright standing (*p*=0.013). A main effect of POSTURE was found for the L1/2 vertebral angle – the joint was more flexed during the angled condition than upright standing (*p*=0.0252).

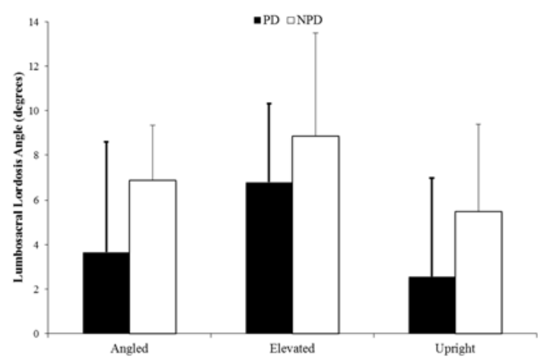

Figure 1. LSL angle in three standing postures

Discussion and Conclusions: Pain and non-PDs stand differently in their normal upright standing posture, with PDs standing with less flexion of their LSL than non-PDs. Based on the intervention results, elevating one leg onto a raised surface may be the best candidate to bring lumbar spine angle more in line with non-PD behaviour and allowing for increased movement of the lumbar spine during prolonged standing if a person were to cycle between the level ground and elevated standing position.

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STOOPING AND CROUCHING POSTURES: THE APPLICABILITY OF THE INVERTED PENDULUM MODEL

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Introduction: Currently, it is unknown whether the inverted pendulum model is applicable to stooping or crouching postures; however, many studies have used an inverted pendulum to model similar dynamic postures [1]. As such, the aim of this study was to determine the degree of applicability of the inverted pendulum model to these postures, by examining the relationship between the centre of mass (COM) acceleration and centre of pressure (COP)-COM difference. This relationship is a defining feature of the inverted pendulum model, where in quiet stance, the COM acceleration of the pendulum is proportional to the difference between the COP-COM [2].

Methods: Ten young adults participated in the study (age: 22.8 (2.5) y; height: 1.7 (0.1) m; mass: 73.2 (16.6) kg). Three-dimensional kinematics were collected using a four-bank Optotrak Certus system (Northern Digital Inc., Waterloo, ON) at 32 Hz, and used to calculate the whole body COM position via a 15-segment model. The COP was determined using the force and moment signals from a floor-mounted force platform, (AMTI, Watertown, MA); sampled at 512 Hz. Every participant performed each of the standing, stooping and crouching postures once, for 20 seconds. For both the anterior-posterior (AP) and medio-lateral (ML) directions, the time-varying acceleration of the COM and the COP-COM were computed. The relationship between these two variables was then determined using Pearson's correlation coefficients.

Results: For the standing, stooping and crouching postures, average (SD) correlation coefficients were -0.852 (0.066), -0.785 (0.125) and -0.803 (0.115) in the AP direction and -0.818 (0.100), -0.935 (0.047) and -0.766 (0.211) in the ML direction, respectively. A 2 x 3 ANOVA revealed a posture x direction interaction effect ($F(2,18)=4.033$; $p=0.036$). Along with no main effects of posture in the post-hoc one-way ANOVAs (AP: $p=0.418$; ML: $p=0.053$), pairwise comparisons also revealed that in the ML direction, standing was not different from stooping ($p=0.121$) or crouching ($p=0.612$).

Conclusions: Based on the results of this study, it appears as though the inverted pendulum model for AP and ML control is indeed applicable for stooping and crouching postures. Due to their importance in completing activities of daily living, future work should investigate if the control of these postures is similar to that proposed by Winter et al. [3] for quiet stance, namely through the plantar/dorsiflexors for AP sway, and the hip load/unload mechanism for ML sway.

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Ontario Biomechanics Conference Podium Presentations
14^{th}-16^{th} March 2014

Podium Sessions C: Saturday 15^{th} March 11:00am - 12:00pm

Podium Session	Presenter	Title
C: Occupational Biomechanics and Musculoskeletal Disorders Saturday 15^{th} March 11:00am – 12:00pm	Alan Cudlip	Upper extremity muscular demands during materials handling tasks while sitting and standing
	Jessica Cappelletto	Lower-body bracing during kinematically constrained tasks
	Julian Liebregts	Right angle power tool physical demands with assembly work
	Scott Dainty	Joint loading, postures and the link with pain reporting during the preparation of espresso-based beverages
	Spencer Savoie	Dynamic shoulder strength prediction for ergonomic applications
	Tara Diesbourg	Spinal loads in daycare workers when lifting children: A pilot study

UPPER EXTREMITY MUSCULAR DEMANDS DURING MATERIALS HANDLING TASKS WHILE SITTING AND STANDING

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Introduction: Sedentary work relates to musculoskeletal discomfort in both prolonged sitting and standing [1, 2]. However, research regarding sit-stand workstations has not quantified upper extremity exposures and muscular demands. This study quantified upper extremity demands associated with four manual materials handling (MMH) performed while sitting and standing.

Methods: 40 participants (20 M, 20 F) completed four MMH tasks (static 40N push, static 40N pull, weighted bottle transfer on tabletop, light assembly on tabletop) while seated and standing. Task locations and workstation heights were set relative to participant stature to conform to guidelines for light assembly work [3]. Surface electromyography (EMG) was collected for 4 muscles (middle deltoid, upper trapezius, supraspinatus, infraspinatus) bilaterally at 1500 Hz (Noraxon Telemyo 2400 T G2), linear enveloped and normalized to muscle-specific maximal outputs. These data were sorted into amplitude probability distribution functions (APDFs). A 2-way ANOVA (4 tasks * 2 configurations) determined the influence of task and configuration on normalized EMG at APDF levels of 0.1, 0.3, 0.5, 0.7 and 0.9.

Results: Interactions between configuration and task appeared in UTRP and SUPR bilaterally across all APDF values tested ($p<0.01$, Figure 1). Seated work resulted in higher muscular activity in the left SUPR, and UTRP bilaterally ($p<0.05$). A main effect of MMH task existed for all muscles examined ($p<0.01$). Peak muscle activity was highest during the weighted bottle transfer, with the greatest activity seen in INFR bilaterally ($p<0.01$, Figure 1C).

Discussion and Conclusions: Moving from standing to seated configurations resulted in increases in UTRP and SUPR muscular activity in identical tasks despite the use of current and consistent ergonomic guidelines. At low (0.1) levels, the assembly task required higher activity levels, increasing fatigue risk over prolonged periods. Peak activity levels (0.9) during the transfer task were highest for all muscles, averaging 13-17 %MVC. Future guidelines should consider both task and workplace configuration together to minimize musculoskeletal risk.

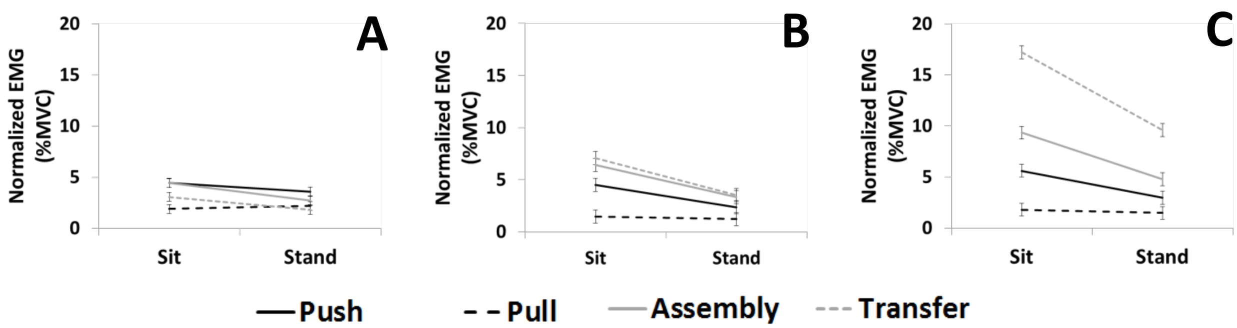

Figure 1. Normalized EMG of left infraspinatus at APDF values of 0.1 (A), 0.5 (B) and 0.9 (C) across tasks (push, pull, transfer, assembly) and workstation configurations (seated and standing).

References: [1] Juul-Kristensen & Jensen (2005). *Occup. Env. Med*, 62(3), 188-194.
[2] Macfarlane et al (1997). *Spine*, 22(10), 1143-1149.
[3] National Institute of Occupational Safety & Health – NIOSH Publication 2010-106.

LOWER-BODY BRACING DURING KINEMATICALLY CONSTRAINED TASKS

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Introduction: In many occupational tasks, environmental constraints limit how close a worker can place their body to a desired task element. Although this provides an obstacle when performing the task, workplace obstructions can also be used advantageously by a worker to externally support their body by means of bracing. The use of bracing has been shown to make tasks easier, by increasing the force generating capacity at the task hand [1]. The purpose of this study was to identify how a worker's posture would differ when a task must be performed with a constrained reach, both with and without the option to externally support against the lower body.

Methods: A total of 18 females (22.2 ± 1.2 years, 64.6 ± 11.3 kg) participated in this study. At each combination of 2 task hand heights ("Low" and "High" at 0.4 and 0.6 of stature, respectively) and 2 reaches ("Close" and "Far" at 0.9 and 1.2 of arm length, respectively), participants performed 6 exertions comprised of 2 loads (27.5 and 55 N) and 3 directions (up, down, and pull). They were able to choose if they would brace during the first 24 trial exertions. After each free choice condition was collected, trials were repeated with either a forced brace or unbraced, depending on what had been chosen initially. 3D motions were recorded using 11 Raptor-4 infrared cameras (Motion Analysis Inc, Santa Rosa, CA.). Joint angles and moments were obtained using Jack ergonomic software (Siemens AG, Ann Arbor, MI).

Results: Elbow flexion angle was an average of 14.7° higher when bracing, compared to no bracing, for all exertion directions ($p<0.0001$). The mean resultant shoulder angle, in non-braced conditions, was significantly higher than when braced at all task hand locations except for High-Close ($p<0.001$). The trunk flexion angles were significantly higher for both Low task hand locations during braced trials, yet decreased by an average of 21.8° at High-Far ($p>0.001$).

Discussion: When bracing, participants adopted a posture that allowed the shoulder of their task arm to be closer to the point of exertion (Figure 1). Flexing the trunk and twisting the right shoulder forward, combined with a more flexed task arm and reduced shoulder rotation, allowed for reduced demands on the shoulder. The primary application of this research is to aid ergonomists in accurately predicting how a worker will approach tasks with constrained reaches, especially when bracing surfaces are available, during proactive ergonomic analyses.

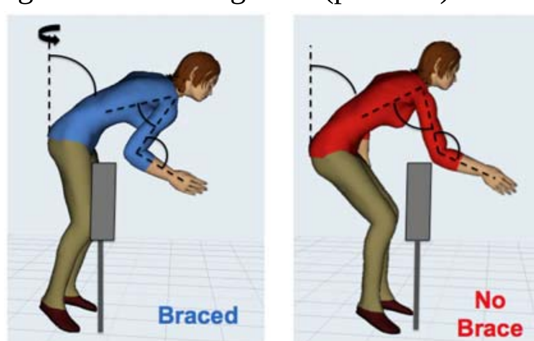

Figure 1: Posture of braced (left) vs. unbraced (right) exertion at Low-Close. Note the increased trunk flexion and decreased shoulder and elbow rotation when braced, allowing the participant to position their shoulder closer to the task location.

Reference:

[1] Jones, M et al. (2013). The effect of bracing availability on one-hand isometric force exertion capability. Ergonomics, 56 (4); p 667-81.

RIGHT ANGLE POWER TOOL PHYSICAL DEMANDS WITH ASSEMBLY WORK

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Introduction: Workplace injuries are commonly associated with the use of right angle power hand tool (RAPT) on automotive assembly lines [1]. While companies have placed arbitrary limits on RAPT torque, it is not yet understood how worker discomfort is affected by RAPT types or torque rundown patterns. Before simulating these tasks in the lab, we must know how RAPTs are used in the workplace.

Methods: A survey was conducted at an automotive assembly plant to document; tool characteristics (type, target torque (TT)), task demands (relative horizontal/vertical position of the midpoint of the hands, force exertion direction), and operator strategy/posture (trigger/support hand choice, trigger/support hand forearm posture, support hand location on the tool, tool orientation (using a "clock" method), and stance) data. For exertion direction, position, and handle orientation, only the 439 standing elements were evaluated. For the rest, all elements (n = 456) were analyzed.

Results: The most commonly used RAPT type was electric (DC) at 76.5% (average TT = 30.6±20.0 Nm), followed by pneumatic at 20.6% (TT = 14.4±10.2 Nm). The task hands were most commonly observed in the "close" reach range (defined as within an arm's reach without trunk flexion) at 85.4%, while the most common vertical range was at the "waist" (55.4%), followed by the "chest" (23.0%). The most common combined ranges were "close-waist" (46.5%) and "close-chest" (20.5%). Overall, the most common force directions were down (38.0%) and anterior (23.9%). Notably, directions were observed to gradually transition from down to up as vertical reach increased. For these down and anterior exertions, the RAPT handle was most commonly held at "5" and "6" o'clock, respectively. For lateral and medial exertions, the handle was most commonly at "9" o'clock. The right hand was mostly used for triggering the tool (81.8% with 60.3% with a pronated wrist). A support hand was applied for 66.7% of all cases. The support hand was most commonly placed over the spindlehead (66.1% with 63.2% with a neutral wrist) followed by at the mid-handle (30.3% with 45.7% with a supine wrist).

Discussion and Conclusions: It was interesting to note that workers most often placed their hand over the spindlehead, most likely to stabilize the RAPTs end effector over the fastener. Consequently, they depended solely on the trigger hand to counter the reaction force at the handle. Workers tended to orient the RAPT handle so that it was close to their body, effectively reducing the required horizontal reach, subsequently reducing shoulder flexion and/or trunk flexion. Preliminary mechanical testing of various RAPT types has shown that there is very wide variety of torque rundown strategies that are programmed into the tools, yet the ergonomic impact of these torque profiles are not currently well understood. Future studies must include biomechanics and psychophysics assessments of RAPT rundown profiles to determine the optimal strategies for reduced injury risk. This survey will be used to guide the design of such studies to best reflect the demands actually experienced in industry.

References: [1] U.S. Bureau of Labor Statistics, 2011.

JOINT LOADING, POSTURES AND THE LINK WITH PAIN REPORTING DURING THE PREPARATION OF ESPRESSO-BASED BEVERAGES

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Introduction: Although not considered a significantly high-risk occupation for low back pain (LBP), baristas work long hours on their feet while performing tasks that put repetitive sub-threshold loads on their low back. Sub-threshold loads alone are likely not a concern, but over time as they accumulate, they may become a contributor to LBP. Baristas experience these sub-threshold loads on a continuous basis while making espresso-based drinks.

Methods: Ten baristas participated in the current study. Three videos, approximately 1-2 minutes in length, were collected for each participant while they prepared espresso-based beverages. After collection, the videos were converted to AVI format, reduced from 30 Hz to 3 Hz [1] and analyzed by 3DMatch (J.P. Callaghan, University of Waterloo). Two one-way ANOVAs were performed: the first tested peak and cumulative low back loading variables with LBP (yes/no) as the independent factor. The second tested peak and cumulative shoulder moment variables with shoulder pain (yes/no) as the factor. Finally, a two-way ANOVA was conducted on percentage of time spent in different non-neutral posture ranges with shoulder pain and LBP as factors.

Results: Increased peak low back compression was found in baristas with LBP ($p=0.03$). Peak and cumulative adductor moment ($p=0.002$; $p=0.003$; respectively), extensor moment ($p=0.02$; $p=0.005$; respectively), and internal rotation moment ($p=0.002$; $p=0.01$; respectively) about the dominant shoulder were higher for individuals with shoulder pain. Baristas who experienced LBP spent more time in moderate as compared to neutral shoulder flexion ($p=0.01$) and neck axial twist ($p=0.01$), and baristas who experienced shoulder pain spent more time in moderate trunk lateral bend ($p=0.01$), trunk axial twist ($p=0.01$), and shoulder abduction ($p=0.03$).

Discussion: Increased peak compression in those with LBP and increased shoulder moments in those with shoulder pain may be, in part, due to the process in which the espresso is prepared. It was observed that the mode of tamping, or compressing the espresso for brewing, was done manually in the cafes where baristas with LBP and shoulder pain worked. In particular, the use of a manual tamper requires awkward upper limb and trunk postures and the application of a substantial downward force (approximately 230N). In terms of the observed increases in the amount of time spent in moderate rather than neutral postures in those with reported LBP and shoulder pain, it is probable that these individuals have adopted postures that are not as sparing to their joints and as a result, may be increasing their likelihood of experiencing pain in these regions. The findings from this study can be used to create new or redesign existing tools used by baristas in order to reduce joint loading and the time spent in non-neutral postures.

References: [1] Andrews DM et al (2003). Determining the minimum sampling rate needed to accurately quantify cumulative spine loading from digitized video. Appl Ergon 34; p. 589-95.

DYNAMIC SHOULDER STRENGTH PREDICTION FOR ERGONOMIC APPLICATIONS

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Introduction: Dynamic strength is critical in the ergonomics of job design. However, measuring dynamic strength in the field is problematic. Recent research has demonstrated a high correlation between slow isokinetic and isometric shoulder strength in the frontal plane (Harbo et al 2012). There remains a need to predict dynamic strength from static strength measurements. Thus, the purpose of this study was to create regression models to predict dynamic strength in multiple planes using isometric strength data.

Methods: Fifteen healthy women completed maximum isokinetic and isometric shoulder exertions using an isokinetic dynamometer (Biodex System 3, Biodex Medical Systems, NY, USA) in the sagittal (0°), frontal (90°), and 45° planes. Isokinetic shoulder strength was recorded at 5 speeds (30, 60, 90, 120, and 180°/s) for concentric flexion and extension contractions. Isometric shoulder flexion and extension strengths were recorded at four elevation angles (30, 60, 90, and 120°) in each plane. Data were analyzed using a two-way within measures ANOVA with post hoc testing. Six multiple linear regression models were created, one for each plane and exertion direction.

Results: Maximal isometric and isokinetic torques seen in Table 1 were comparable to the literature. Isometric torques were found to be significantly greater than the isokinetic torque at any speed ($p<0.001$), and torques at 180°/s were lower than all other speeds ($p<0.05$). Flexion and extension torques differed significantly for isometric exertions ($p<0.001$) but not for isokinetic exertions at any speed. The multiple linear regression models included isometric strength, speed, and elevation angle as predictor variables and had explained variance (r^2) ranging from 0.66 to 0.93 ($p<0.001$). Speed explained the most variance in dynamic strength, explaining 10-78% more variance than both isometric strength and elevation angle combined.

Discussion and Conclusion: The regression models predicted dynamic strength well for participants of average strength. A general trend was also noted that isokinetic strength at typical working speeds (60°/s) was approximately 2/3 of the maximal isometric strength at a given elevation. These equations provide needed support for ergonomic applications by improving the relationship of shoulder torque production to the speed of work.

Reference: Harbo, T, Brincks, J, & Andersen, H (2012) *Eur J Appl Physiol*, 112:267-75.

Table 1: Mean Peak Torque (Nm) with standard error in parentheses.

Plane	Exertion	Isometric	30°/s	60°/s	90°/s	120°/s	180°/s
0°	Flexion	51.7 (3.6)	33.3 (2.0)	31.9 (1.8)	30.8 (1.9)	30.0 (1.9)	26.0 (1.7)
	Extension	56.1 (3.4)	36.6 (2.6)	36.5 (2.6)	37.7 (2.9)	35.7 (2.6)	34.9 (3.6)
45°	Flexion	43.5 (2.7)	27.8 (1.4)	28.0 (1.3)	27.8 (1.4)	26.0 (1.4)	23.9 (1.0)
	Extension	54.9 (2.5)	30.3 (2.0)	30.3 (2.1)	29.2 (2.0)	28.5 (2.2)	24.3 (2.4)
90°	Flexion	48.0 (2.9)	31.7 (2.0)	30.2 (1.9)	28.4 (2.0)	26.9 (1.7)	24.5 (1.4)
	Extension	50.9 (3.1)	28.4 (1.7)	29.8 (1.7)	29.9 (2.2)	29.9 (2.0)	23.9 (2.8)

SPINAL LOADS IN DAYCARE WORKERS WHEN LIFTING CHILDREN: A PILOT STUDY

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Introduction: Low back injury can occur through two mechanisms: 1) lifting a load that exceeds the compressive tolerance of the tissue, 2) repetitive lifting of a load at or below the tissue tolerance [1]. The purpose of the study was to determine whether daycare workers are at risk for these injury mechanisms such that recommendations for changes to the work environment (ie: furniture height) can be made to reduce these risks.

Methods: University of Michigan 3D-SSPP software was used with images collected during observation of 6 daycare educators in the workplace, in order to estimate lumbar compressive forces. Three educators worked with infants (age <18 months), and 3 worked with toddlers (age 18-30 months). Additionally, Recommended Weights of Lift (RWL) were calculated for each age group using the NIOSH lifting equation [2]. This equation was used because it accounts for various other factors related to the lift (ie: lift frequency, load distance, and coupling) [2].

Results:

NIOSH RWL: During the 3.5 hour observation period, the daycare workers were observed to lift an average 37.4 times in the infant group and 28.4 times in the toddler group. The actual weights lifted in the daycares were found to exceed the RWL in both cases (Figure 1).

Low back compression forces: Mean lumbar compressive forces of 2162N (range: 1084-2944N) and 2691N (range: 1134-4318N) were observed for the infant and toddler workers respectively. According to NIOSH, low-back compressive forces of 3400N [2] are acceptable for 75% of females; however in the toddler group the compressive forces occasionally exceeded this limit.

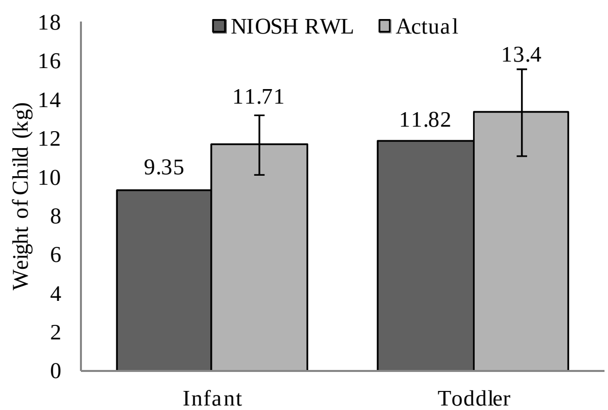

Figure 1: Comparison of the NIOSH RWL and the mean weight for the children in each age group.

Discussion & Conclusions: While the current analysis provides a general idea of the situation in daycares, it is essential to further investigate the loads imposed on these workers. This analysis focused solely on lifts while standing, and not on the lifts that occurred while seated or kneeling. Additionally, 3D-SSPP analyzes lifting statically and does not take into account the accelerations caused by movement of the child in the workers' arms. Lastly, as child weight and lift frequency cannot be modified, it is important to identify other factors that can.

References:

[1] McGill, S.M. (1997) The biomechanics of low back injury: implications on current practice in industry and the clinic. *Journal of Biomechanics.* 30(5):465-475.

[2] Waters, T.R., et al. (1993) Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics*. 36(7): 749-776.

Ontario Biomechanics Conference Podium Presentations
14th-16th March 2014

Podium Sessions D: Saturday 15th March 1:30pm - 2:20pm

Podium Session	Presenter	Title
D: Methods, Instrumentation, Analysis, Modelling I Saturday 15th March 1:30pm – 2:20pm	Alex MacIntosh	Modelling the index finger: A comparison of computational methods to assess joint loading with submaximal dynamic tasks
	Binh Ngo	Testing forearm EMG protocols for normalizing grip strength
	Danielle Devries	The authentication of a human posture prediction tool used for virtual ergonomic analyses
	Jaclyn Chopp-Hurley	Probabilistic evaluation of predicted force sensitivity to muscle attachment and glenohumeral stability uncertainty
	Malinda Hapuarachchi	A construct validity study of the Functional Movement Screen™

MODELLING THE INDEX FINGER: A COMPARISON OF COMPUTATIONAL METHODS TO ASSESS JOINT LOADING WITH SUBMAXIMAL DYNAMIC TASKS

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Introduction: Assessing finger joint motion and loading is essential for preventing musculoskeletal disorders of the hand. Biomechanical modelling provides valuable information about joint kinematics, loads, and musculotendinous forces. Given the variety of computational methods available, there is a need to identify nuances between modelling approaches. This study aimed to incorporate kinematics and forces into (i) a link segment (LS) model of the hand, and (ii) a musculoskeletal model (MS) of the upper limb, facilitating a comparison of joint moments and forces.

Methods: Index finger kinematics were recorded from eight participants performing 5 sub-maximal dynamic fingertip pressing tasks while maintaining a 10N vertical force. Motion capture data were used to develop a LS model of the hand in Visual3D (C-Motion, Germantown, MD) (Cocchiarella et al., 2013). Using open-source modelling software, (Fig. 1, OpenSim 3.1, Simbios, Stanford, CA), raw marker coordinates, and kinematic data from the LS model the experimental motions were recreated in a MS model of the upper limb (Kociolek and Keir, 2011). In the LS model, net joint moments and reaction forces were calculated using a standard inverse dynamics. In the MS model, muscle forces estimated via static optimization were included in the force analysis.

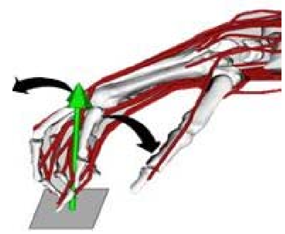

Figure 1: MS model. Green (straight) arrow indicates reaction force. Black arrows indicate motion.

Results: LS and MS model joint angle profiles were well correlated, $r \geq 0.95$. Mean flexion-extension net joint moments were better correlated than ab-adduction moments ($r = 0.83$ and 0.72, respectively). MCP joint compression was higher in the MS compared to the LS model (Mean ± SEM: MS: 34.80 ± 4.40 N, LS: 1.23 ± 1.62 N; $p < 0.03$). MCP shear was directed anteriorly in the MS model (9.13 ± 1.49 N) and dorsally in the LS model (6.76 ± 1.65 N).

Discussion: While finger joint angles were well correlated, discrepancies in joint moments may be attributed to differences in joint mobility. Since each segment in the LS model has 6 DOF, accessory motions and joint translations were allowed, as compared to only 4 rotational DOF in the entire finger of the MS model. Moreover, extensor muscle forces were under predicted in the MS model, likely due to the optimization criteria used to estimate muscle forces. Considering the complexity of work tasks involving the fingers, including intrinsic musculotendinous structures and EMG-assisted optimization may improve future models.

References:

[1] Cocchiarella, D. et al., (2013). An unconstrained kinematic model of the hand. Presented at the 2nd *International Symposium on Digital Human Modelling 2013* 11-13 June, Ann Arbor, MI.

[2] Kociolek, A.M. and Keir, P.J. (2011). Modelling tendon excursions and moment arms of the finger flexors: Anatomic fidelity versus function, *J. Biomechanics*, Vol. 44 No.10, pp.1967-1973.

TESTING FOREARM EMG PROTOCOLS FOR NORMALIZING GRIP STRENGTH

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Introduction: Maximum electromyography (EMG) contractions are typically used to normalize trial data. Forearm EMG studies traditionally use the same "Reference Task", an isometric maximal voluntary grip task in a neutral wrist posture, to normalize data (1, 2). This project's objectives are:

1) To test other maximal grip tasks found in the literature
2) To identify which tasks produce the highest EMG signal
3) To suggest a new protocol which future researchers can use to normalize EMG data for the forearm

Methods: This study so far had 3 participants (2 males, 1 female). Surface electromyography (sEMG) peak amplitudes were found for 6 muscles: flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), flexor digitorum superficialis (FDS), extensor carpi ulnaris (ECU), extensor carpi radialis (ECR), and extensor digitorum (ED)(2). Skin was shaved and abraded with alcohol and Nuprep Skin Prep Gel (Weaver and Co., Colorado, USA). Oval, bipolar, Ag-AgCl electrodes with an inter-electrode distance of 2 cm (Ambu Bluesensor N, Ballerup, Denmark) were placed in accordance to SENIAM and connected to an 8 channel Octopus AMT-8 differential EMG system (Bortec, Alberta, Canada). The AMT-8 system connected to a 12-bit NIDAQ card and trials were collected using NIAD 3.0 (National Instruments, Texas, USA) at 2048 Hz. Participants were seated with elbows flexed at 90° and wrists in a neutral position. Two sets of 20 randomized maximal voluntary electrical activation (MVE) tasks were each performed for 5 seconds. The grip tasks differed in wrist posture, linear force directions and moment directions; there was also a resisted finger extension task (3). Moments were applied with a bladeless hacksaw frame. Between tasks, participants rested for at least 2 minutes. Surface EMG signal was band passed filtered from 10-500 Hz using a 2^{nd} order Butterworth Filter. The bias was removed, the signal was full wave rectified and linear enveloped using a 2^{nd} order, single pass, low pass Butterworth filter at 3 Hz(2). For each muscle, peak EMG amplitude was found using a 1 second moving average and normalized to the maximum amplitude from the 20 different grip tasks (3). EMG amplitudes of each task will be compared to the reference task EMG amplitudes using one way, repeated measures ANOVAs.

Results: Pilot study data from 3 participants indicated that moments produced the highest EMG amplitudes. The reference task performed, at best, in 6^{th} place when compared to the other tasks. The pronation and extension tasks produced the highest EMG amplitude signals in the forearm flexors and extensors, respectively.

Conclusion: This study is ongoing and the full results will be reported at a later date.

References:

(1) Greig M & Wells, R. (2004) *Ergonomics*, 47(1): 41-58.
(2) Yung M & Wells, R. (2013) *J. Elec. & Kin*, 23(3): 664-672.
(3) Greig M & Wells, R. (2008) *Ergonomics*, 51(8): 1238-1257.

THE AUTHENTICATION OF A HUMAN POSTURE PREDICTION TOOL USED FOR VIRTUAL ERGONOMIC ANALYSES

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Introduction: Numerous companies have elected to use computer aided digital human simulation tools, utilizing human based manikins, to identify and resolve ergonomic issues early in the development and/or manufacturing processes of products. It has been noted that manual posturing of digital models can be time consuming [1] but Jack™ human simulation software (Siemens, Munich, Germany) has incorporated a human posturing tool (HPT) which predicts whole body posturing necessary for human-product interaction. While the HPT offers the advantage of being repeatable, easy to use and produces postures with a reasonable degree of realism, the exact accuracy of resulting postures, relative to what a worker would do in the work environment, has yet to be quantified.

Methods: Three one-handed exertion tasks and three two-handed exertion tasks (pull-back, push-down and push-forward) were simulated in the laboratory. 30 subjects were then captured completing all six exertion tasks using Vicon™ motion tracking camera system (Vicon, Oxford, UK) and an AMTI™ force plate (AMTI force and motion, Massachusetts, USA). The data collected from Vicon™ were then linked to the Jack™ manikin that mimicked the corresponding subject. The Jack™ manikin was then posed in the posture that the subject had reached to complete each task. A second Jack™ manikin was then brought into the scene and the HPT was run to predict the posture that Jack™ believes that individuals should take to complete the given task (Figure 1). The following dependent variables were compared from between the Jack manikin driven from real humans (real) and that predicted from the HPT: L_{4-5} compression force, L_{4-5} anterior/posterior shear force, L_{4-5} lateral shear force and % capable static strength of all joints. Each dependent variable was statistically analyzed using a paired sample t test ($p<0.05$).

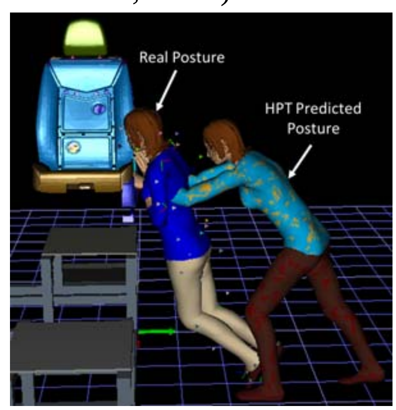

Fig 1: Jack manikins comparison

Results: For all tasks, results show statistical differences for L_{4-5} compression force (HPT < real), L_{4-5} anterior/posterior shear force (HPT < real) as well as the L_{4-5} lateral shear force (HPT > real) were found. In addition to these forces on the L_{4-5} joint, significant differences are seen in the percent capable strengths in those of the right and left elbow (HPT < real), right humeral rotation (HPT > real) and the trunk flexion and extension (HPT > real).

Discussion and conclusion: Of the six tasks tested, three tasks (one-hand push forward, two-hand pull back and two-hand push forward) resulted in having significant differences in more than three of the ergonomic analyses performed. From these results we have determined that Jack™ HPT aims to minimize the shoulder joint moment by extending the arm. In the real world subjects moved closer to complete the force exertion which increased trunk flexion angle and decreased shoulder angle to less than full extension. This suggests that more variables are required to predict human postural behaviour that was is currently be utilized. It is critical that HPT is improved to more closely match those postures of the real world, and to do this additional research is needed.

References:
[1] Raschke, U., Kuhlmann, H., & Hollick, M. (2005). On the design of a task based human simulation system. SAE International. Rep. No. 2005-01-2702.

PROBABILISTIC EVALUATION OF PREDICTED FORCE SENSITIVITY TO MUSCLE ATTACHMENT AND GLENOHUMERAL STABILITY UNCERTAINTY

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Introduction: Computational modelling has considerable utility for biomechanics research, notably its ability to estimate internal muscular demands given limited input information. However, several assumptions regarding model parameters and constraints may influence model outputs. This study evaluated the influence of model parameter variability on predicted rotator cuff muscle force during humeral rotation tasks. Additionally, relative non-dimensionalized sensitivity factors assessed which parameters were more contributory to output variability.

Methods: Upper extremity internal and external rotation tasks were simulated using the three-dimensional static strength prediction program (3D SSPP) (University of Michigan, Ann Arbor, MI). Extracted kinematic data, along with anthropometric data, was used as input into the existing SLAM model [1]. External hand forces were applied and model parameters, specifically rotator cuff muscle attachment locations and glenohumeral stability constraints, were estimated using the best available distributions. Finally, the variability of these parameters was treated stochastically in the model, to obtain distributions of predicted rotator cuff muscle forces.

Results: Modest model parameter variation resulted in considerable variability in predicted force, with origin-insertion locations most influential. The largest variability in predicted forces occurred for the subscapularis muscle at neutral with a mean difference between lower (1%) and upper (99%) confidence intervals of 33.0 ± 9.6% of normalized muscle force and a maximal difference of 51% (Fig. 1). Infraspinatus and supraspinatus muscles elicited maximal differences of 15.0% and 20.6%, respectively, between confidence limits with model parameter variation. Variability was not largely influenced by anthropometric differences, despite divergence in predicted force magnitudes.

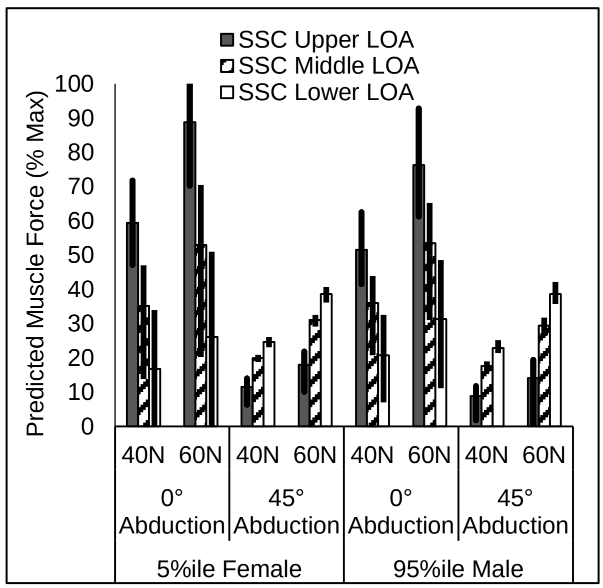

Fig. 1 Predicted muscle force for the three lines of action (LOA) of the subscapularis (SSC) muscle during internal rotation exertions. Error bars represent a 1 to 99% confidence interval.

Discussion: The findings reinforce the importance of potential model parameter variability in musculoskeletal modelling, highlighting the necessity of incorporating geometric variation in the prediction of rotator cuff muscle forces. Variation in origin and insertion locations resulted in output variability up to 50% of maximal capability. This implies a possibly wide range of tissue-specific task demands within even an anthropometrically similar population, subsequently leading to the possibility of different physical exposure levels and subsequent health outcomes.

Reference: [1] Dickerson CR et al. *Comp. Methods Biomech. Biomed. Eng*. 10:389-400, 2007

A CONSTRUCT VALIDITY STUDY OF THE FUNCTIONAL MOVEMENT SCREEN™

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Introduction: The Functional Movement Screen™ (FMS) is a tool purported to identify personal risk factors for musculoskeletal injuries [1]. Although its reliability has been studied extensively, there have been few attempts to examine its construct validity. Our objectives are to: (1) describe the distribution of joint range-of-motion (RoM) measurements and FMS scores among a student-athlete population; and (2) examine whether associations exist between joint RoM and FMS scores.

Methods: Seventy-four varsity athletes (33 men, 41 women) from the University of Toronto basketball, volleyball, ice hockey, and soccer teams have participated to date. Pre-existing musculoskeletal injuries or pain do not exclude participation unless the athletes have been advised by a physician to avoid any joint motion. During one half of the data collection session, a licensed therapist measures ankle dorsiflexion, first metatarsophalangeal joint dorsiflexion, hip extension, hip flexion, hip adduction, hip internal rotation, shoulder flexion and shoulder internal rotation RoM bilaterally using a manual goniometer. During the second half of the session, the FMS is administered via standardized protocols [1] and synchronized video is recorded from the frontal and sagittal planes (©Dartfish, Fribourg, Switzerland). Order of exposure to the FMS and RoM protocols is randomized across participants, and a minimum of 5 min of passive recovery is provided between the protocols. Published criteria [1] are being used to grade the FMS tasks via the video recordings. Descriptive statistics of the athletes' physical characteristics are being compiled together with the distributions of their RoM measurements and FMS scores. Initially, RoM means (with 95% confidence intervals) are being compared against each of the seven FMS task scores. When our target sample size is met (N=120), analyses of variance will be used to test whether statistically significant associations exist between RoM measures and FMS task scores.

Expected Results: We hypothesize that athletes who exhibit lower RoM measures will score lower on the FMS tasks most likely (based on biomechanical rationale) to be affected by RoM capacity (i.e., deep squat, hurdle step, in-line lunge, active straight leg raise, and shoulder mobility tasks). We do not anticipate that RoM measures will be associated with scores on the FMS trunk stability push-up or rotary stability tasks. Ultimately, the results of this research may assist with the development of a cost-effective injury risk screening strategy for athletes.

References:
[1] Cook, G. et al. (2006). *Movement: Functional Movement Systems: Screening, Assessment, and Corrective Strategies*. Santa Cruz, California, USA: On Target Publications.

Ontario Biomechanics Conference Podium Presentations
14th-16th March 2014

Podium Sessions E: Saturday 15th March 2:35pm - 3:25pm

Podium Session	Presenter	Title
E: Clinical Biomechanics, Rehabilitation, and Fitness Saturday 15th March 2:35pm – 3:25pm	Ayesha Johnson	Relationships between knee kinematics and the knee adduction moment in yoga postures
	Brendan Cotter	Can insoles reduce ground reaction forces?
	Iris Levine	The influence of body geometry and soft tissue distribution on distribution of loads during impacts to the hip
	Meagan Warnica	Characterizing cycling/motor vehicle accidents causing litigation in Southern Ontario
	Mike Davison	Thigh intramuscular fat is related to decreased knee extensor and flexor power in women with knee osteoarthritis

RELATIONSHIPS BETWEEN KNEE KINEMATICS AND THE KNEE ADDUCTION MOMENT IN YOGA POSTURES

Ayesha L. M. Johnson[1], Heather S. Longpré[2], Neha Arora[2], Monica R. Maly[2]
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Introduction: Knee osteoarthritis (OA) is characterized by degenerative joint changes that are associated with pain and an elevated external knee adduction moment (KAM) [1]. Thus far, no exercise intervention for knee OA has been developed to limit exposure to the KAM for people with knee OA. Yoga could be ideal for knee OA because specific yoga postures strengthen the body's musculature, while minimizing the KAM. We were interested in predicting the KAM from joint position during specific yoga postures. The purpose of this study was to examine the relationships between knee angles and the KAM for standing yoga postures in women.

Methods: Thirty physically active women between the ages of 18 to 40 years participated. Participants were given a description of each yoga posture, a demonstration, and an opportunity to practice with feedback. The participants performed each yoga postures 3 times and each trial was held for 10 seconds. Bilateral knee kinematics and kinetics were collected during those yoga postures. In addition, participants completed 5 barefoot gait trials at a self-selected speed. This data collection was accomplished using a motion capture system (Optotrak Certus, Northern Digital Inc, Ontario Canada) sampling at 100 Hz, synchronized with 3 in-ground force plates (OR6-7, Advanced Mechanical Technology Inc, Massachusetts USA), sampling at 1000 Hz. During a static 5 second portion of each of the six yoga postures, the mean value for the knee flexion angle (KFA) and the mean KAM were calculated. The peak KAM during gait was calculated to provide a reference value for this sample. Pearson correlation coefficients were calculated between KFA and KAM during each yoga posture.

Results: Mean KAM values for all yoga postures were lower than the peak KAM of 0.42 (0.16) Nm/kg experienced during gait. A positive correlation between KFA and KAM existed in Triangle ($r=0.371$, $p=0.043$) and Warrior ($r=0.425$, $p=0.019$) postures (Figure 1). No correlation was found between KFA and KAM for all other postures ($p>0.05$). Tree posture had the highest KAM, compared to the five other postures. The lowest KAM was produced by Triangle posture.

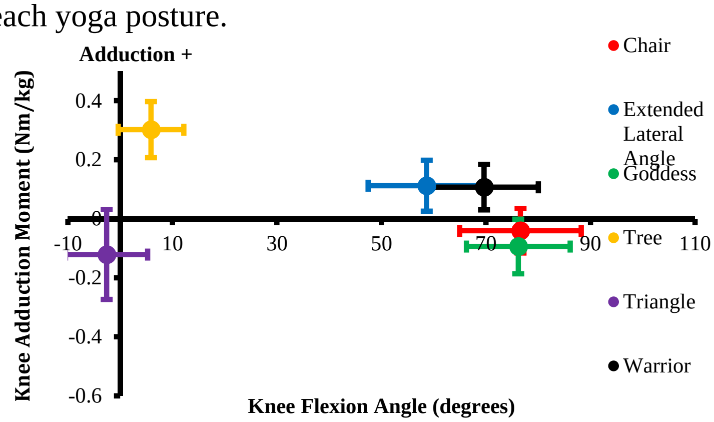

Figure 1: Mean KAM (Nm/kg) and KFA (degrees) for the right leg during the static (5 seconds) yoga postures (n=30).

Discussion and Conclusions: All of the yoga postures elicited a lower KAM than the peak KAM experienced during gait, suggesting that these exercises could be ideal for people with knee OA. However, because a correlation existed between KFA and KAM for Triangle and Warrior postures, minimizing knee flexion in these postures will decrease the KAM. More work is necessary in people with knee OA to confirm whether these exercises are appropriate for knee OA management.

References: [1] Miyazaki, T. et al. (2002). *Annals of the Rheumatic Diseases 61*(7); p. 617-622.

CAN INSOLES REDUCE GROUND REACTION FORCES?

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Introduction: Between 60-85% of individuals experience low back pain (LBP) at least once in their lives [1], putting a financial burden on the economy costing between $80 billion and $625 billion [2]. Walking has been indicated to produce higher loads than standing, specifically during heel contact, making it a potential contributor to LBP [3]. One method currently used to alleviate and prevent LBP is the use of insoles, which are designed to affect change in the lower kinematic and/or kinetic chain [1]. While previous research infers that insoles may reduce LBP through a reduction of shock absorption and/or foot realignment, most orthoses-related LBP research is solely questionnaire based. The purpose of this study was to examine and quantify whether a neuromuscular training insole can alter ground reaction forces immediately after insert placement. A secondary purpose is to determine if there is a relationship between ground reaction forces and the development of transient LBP.

Method: During each session, seven participants completed a series of barefoot and shod walking trials. Walking trials were completed on an instrumented walkway, equipped with two force plates, to quantify ground reaction forces during the left- and right-foot stance phase. Participants completed a series of shod walks before and immediately after placing the specified insoles in their shoes. Barefoot walking trials were completed at the start, middle and end of collection.

Results: Ground reaction forces from the barefoot and shod walking trials were compared before and after insole placement. The vertical GRF in the shod walking trials were shown to be statistically different during both stance phases (Right foot, $p=0.025$ and Left foot, $p=0.002$). Interestingly, the direction of force reduction due to insertion was opposite for the two feet, although the sum of GRF does appear lower with the insoles. These results perhaps suggest that these insoles may cause a total reduction in GRF.

Discussion: The findings of this study have potential to impact the orthotic and insole industry, and to improve the quality of life of individuals suffering from LBP. By providing a scientific explanation for the use of insoles as a treatment for LBP, it is indicating an interrelationship between the lower extremities and the trunk for the development LBP.

References:
[1] Bird and Payne, 1999. *The Foot,* 9: 175-180.
[2] Gore et al., 2012. *Spine*, 3(11): 668-677.
[3] Shabat et al., 2005. *European Spine Journal*, 14: 546-550.

THE INFLUENCE OF BODY GEOMETRY AND SOFT TISSUE DISTRIBUTION ON DISTRIBUTION OF LOADS DURING IMPACTS TO THE HIP

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Introduction: Hip fracture risk is dependent on modulation of applied loads by trochanteric soft tissue via energy absorption, reduction of stiffness and load distribution. Vertical deflection of soft tissue does not fully explain these mechanisms [1], and load prediction models incorporating elements of pelvis-floor contact may more accurately predict and explain force attenuation mechanisms during impact. In this study, we explored relationships between contact area, pressure and peak force during impact, as well as the effect of ultrasound measures of trochanteric soft tissue depth (and more easily accessible surrogates) on impact characteristics.

Methods: Nineteen university-aged females (mean (SD) body mass index=23.7(3.8) kg/m^2, body fat= 29.9(11.8)%) participated in the study. Each underwent lateral pelvis release trials from 5 cm, which involved the lateral aspect of the hip impacting a pressure plate mounted on a force plate. Time-varying force (AMTI, MA, USA) and pressure distribution (RS Scan, Olen, Belgium) were acquired at 500 Hz. Measures of skeletal geometry (segment lengths, pelvis dimensions), body composition (BMI, segment circumferences, skinfold depths), and trochanteric soft tissue depth via ultrasound (SonoSite, Inc., WA, USA) were also acquired.

Results: Peak force (Figure 1a) was most strongly linearly related to total body mass (r=0.712, p=0.001) and effective mass (r=0.818, p<0.001) with weaker but still significant (p<0.05) correlations with height, BMI, greater trochanter-iliac crest height and femur length. Peak pressure (Figure 1b) was negatively associated with pelvic contact area (r=-0.667, p=0.002) and soft tissue depth (r=-0.571, p=0.011). Contact area (Figure 1c) was positively correlated with soft tissue depth (r=0.623, p=0.004), BMI (r=0.511, p=0.025) and percent body fat estimated via skinfolds (r=0.557, p=0.013).

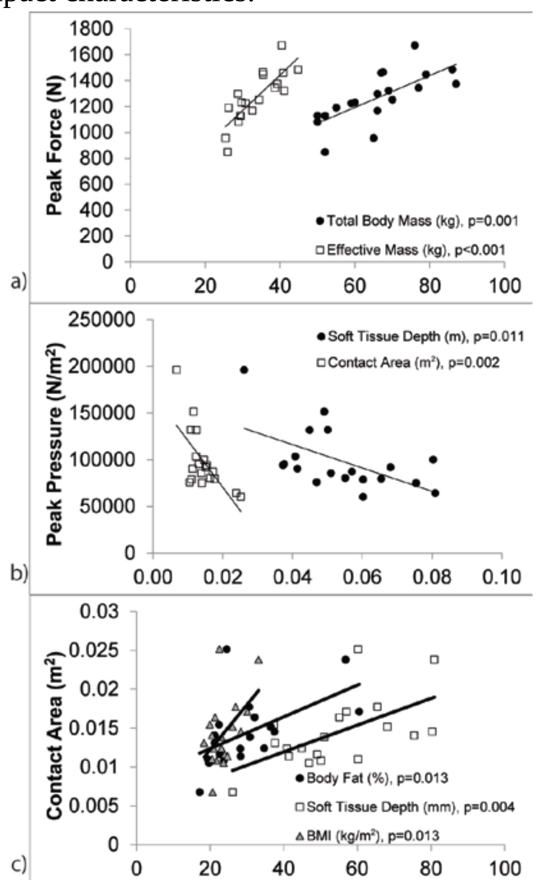

Figure 1: Relationship between elements of body composition and impact characteristics

Discussion and Conclusions: Trochanteric soft tissue depth appears to be a stronger predictor of impact characteristics during lateral falls on the hip than skeletal geometry. Positive results for easily accessible surrogates for soft tissue depth represent promise for incorporating this explanatory factor into more accurate and patient-specific injury prediction models.

References:

[1] Levine, IC et al. (2013). The effects of body mass index and sex on impact force and effective pelvic stiffness during simulated lateral falls. Clinical Biomechanics 28(9); p. 1026-1033.

CHARACTERIZING CYCLING/MOTOR VEHICLE ACCIDENTS CAUSING LITIGATION IN SOUTHERN ONTARIO

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Introduction: Cycling is a common recreational activity, sport and mode of transportation in which helmets can be worn for protection. Cycling accidents ranked second to motor vehicle incidents for non-fatal transport related injuries in Canada [1]. Accident characteristics and injury information about cycling accidents in Canada are typically summarized by analyzing police service or hospital data. However, these sources often underreport or are unable to describe all factors involved in the accidents [2]. Therefore, other resources may provide more information about these types of accidents. The objective of this study was to describe the crash characteristics of cycling/motor vehicle accidents (C/MVAs) in Southern Ontario that resulted in litigation.

Methods: Project descriptions of case files from a professional forensic engineering company (Giffin Koerth, Toronto, ON, Canada) were searched to consolidate all cases of C/MVAs. The remaining 78 cases (from the years 1998-2012) were searched for variables describing driver and cyclist characteristics, crash circumstances, and injury information and described using means, standard deviations, ranges and frequencies. Cyclist injuries were rated using the Abbreviated Injury Scale (AIS) [3].

Results: The majority of cyclists (70.51%) did not wear a helmet and in 58.97% of the cases, one or more head impacts occurred. The ground and windshield were the two most common sources of injury for the cyclists, at 26.32% and 18.42%, respectively. The most commonly injured body area for the cyclists was the head, at 36.84% of all injuries. Figure 1 displays the frequency of injury severity among the 114 total injuries seen in the cyclists.

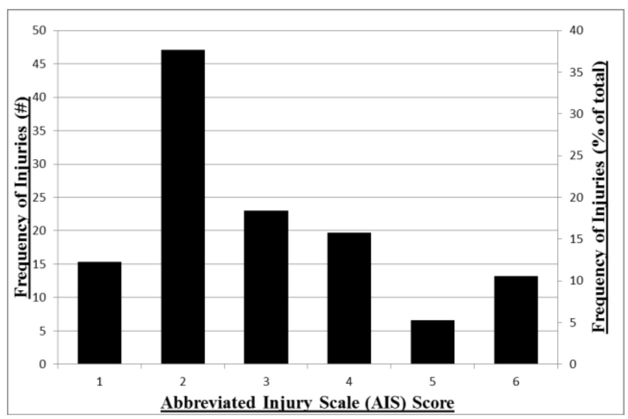

Figure 1: Frequency of cyclist injury and AIS score (AIS 1 – minor, 2 – moderate, 3 – serious, 4 – severe, 5 – critical, 6 – generally unsurvivable)

Discussion and Conclusions: The literature concerning the characteristics of C/MVAs in Southern Ontario is incomplete. The results from the current study provide a more comprehensive view of C/MVAs as they include more specific factors about the incidents than previous reporting techniques. These factors may assist transport safety professionals in designing infrastructure and developing prevention strategies for cyclists. Future steps will include trying to find relationships between injury circumstances and injury outcomes.

References:
[1] SMARTRISK (2009).
[2] Elvik, R. & Mysen, AB. (1999).
[3] Generalli, TA. & Woodzin, E. (2006).

THIGH INTRAMUSCULAR FAT IS RELATED TO DECREASED KNEE EXTENSOR AND FLEXOR POWER IN WOMEN WITH KNEE OSTEOARTHRITIS

Michael Davison[1], Monica R. Maly[2], Karen Beattie[2,3], Peter J. Keir[4], Jonathan D. Adachi[1,3]
[1]Medical Science, [2]Rehabilitation Science, [3]Medicine, [4]Kinesiology,
McMaster University, Hamilton, ON

Introduction: Knee osteoarthritis (OA) is a degenerative disease, which is associated with reduced knee extensor and flexor strength (1). This strength loss is due to the loss of lean muscle mass, pain, neuromuscular inhibition and intramuscular fat (fat within muscle, IMAT) (2). The objective of this study is to determine if IMAT volume in the quadriceps and hamstrings is associated with reduced knee extensor and flexor muscle power in women with knee OA.

Methods: Five women with radiographic, symptomatic knee OA were recruited (age: 63.4±6.6 y; Body Mass Index: 33.4±5.6 kg/m^2). Thigh images were obtained using 3T magnetic resonance imaging (MRI) scanner (General Electric, ON) using the "iterative decomposition of water and fat with echo asymmetry and least-squares estimation" (IDEAL) sequence. This sequence optimizes the contrast of water and fat. Images were analyzed using SliceOmatic (TomoVision, QC) (Figure 1). On each scan, tissues were tagged with a different colour, including muscle, subcutaneous fat, intermuscular fat and intramuscular fat. Each tissue was recorded as total volume (cm^3). Isotonic knee extensions and flexions were completed, with resistance set at 20% of maximum voluntary isometric contraction (MVIC), using a Biodex System 3 dynamometer (Biodex, NY, USA). Extensor and flexor powers were presented in Watts. Surface electromyography (EMG) measured the activation of the vastus medialis (VM) and semitendinosus (ST) (Delsys, MA, USA). EMG amplitudes were normalized to peak activation during MVIC or isotonic contractions. Linear regression determined the relationship between IMAT volume and mean peak power, after controlling for mean peak activation.

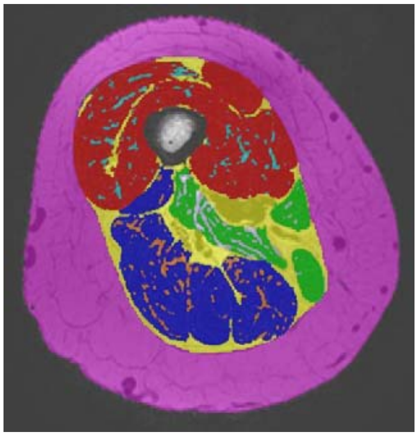

Figure 1. 3T MRI fat-saturated image. Red=quadriceps muscle, blue=hamstrings muscle, cyan=quadriceps IMAT, orange=hamstrings IMAT.

Results: Mean quadriceps and hamstrings IMAT were 43.6±13.5 cm^3 and 46.6±11.1 cm^3. Knee extensor and flexor powers were 385±126 W and 289±70 W. VM and ST activations were 85±11 %MVIC and 64±34 %MVIC. Quadriceps IMAT was negatively related to extensor power (B=-7.848; p=0.062), controlling for VM (B=7.860; p=0.090). Hamstrings IMAT was negatively related to flexor power (B=-7.287; p=0.089), controlling for ST (B=-0.914; p=0.356).

Conclusions: Thigh IMAT is likely negatively related to knee extensor and flexor power. A larger sample will confirm if thigh IMAT is related to muscle power. IMAT may be a therapeutic target for improving muscle function in women with knee OA.

References: [1] Alnahdi A et al. (2012). Sports Health 4(4):284-92.
[2] Kumar D et al. (2013). Osteoarth Cart. 2013 Dec 20.

Ontario Biomechanics Conference Poster Presentations
14^{th}-16^{th} March 2014

Poster Session II: Saturday 15^{th} March 8:00pm - 9:00pm
(Poster Introductions 3:25pm)

Poster#	Poster Presenter	Title
23	Corinne Babiolakis	Relationship between active hip abduction test and standing balance
24	Daniel Vena	Characterizing signal properties of the channeling portion of pedicle screw insertion
25	Erika Lee	Evaluation of exercise rehabilitation in persons with spinal cord injury
26	Jacquelyn Maciukiewicz	Shoulder and low back loading in cashiers: What are the critical contributing factors? A laboratory study
27	Kaitlin Jackson	Does isometric strength training decrease valgus angle during a drop-jump landing in elite female volleyball players?
28	Kristina Gruevski	The effect of local hydration environment on temporal changes in annular thickness and mass
29	Mani Sadeghzadeh	EMG changes of the forearm extensor muscles at different postures
30	Marcus Yung	Identifying measures of fatigue - the CRE-MSD Toronto Workshop
31	Mario Boivin and Devon Day	Neuromechanical control of dual-tasking
32	Marissa Canning	Can plantar cutaneous stimulation via vibration facilitate walking/standing in individuals with an incomplete spinal cord?
33	Maureen Riddell	Influence of input device, desk configuration, and task on spine kinematics
34	Neha Arora	Is knee osteoarthritis a risk factor for non-specific low back pain during lifting?
35	Nicole Green and Elizabeth McLeod	The role of plantar cutaneous mechanoreceptors during gait
36	Patrick Antonio	Investigating the effects of balance, plantar pressure and cutaneous sensitivity in diabetic individuals during stair gait
37	Peter Sheahan	Evaluating the effect of rest breaks on productivity, discomfort, and trunk postural control during prolonged seated typing
38	Reza Khiabani	Association between spasticity and balance impairments in persons post-stroke
39	Sebastian Tomescu	Filtering revisited: Cutoff frequency effects on musculoskeletal simulations
40	Stewart Chisholm	Activities of daily living for unilateral transfemoral amputees: An evaluation of kinematics, kinetics, and trunk muscle activity
41	Tatjana Stankovic	The inter-rater reliability of a novel battery of range-of-motion tests
42	Taya McGillivary	Relationship between the starting angle of thigh-calf contact and anthropometric measures between sex and high-flexion activities
43	Tyler Saumar	Increasing strength through the power of visualization
44	Sulahb Singh	Effects of foot orthotics on spine kinematics during gait and kinetics during free style lifting

RELATIONSHIP BETWEEN THE ACTIVE HIP ABDUCTION TEST AND STANDING POSTURAL BALANCE

Corinne S. Babiolakis, Janessa D.M. Drake
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Introduction: It is well established that individuals with low back pain (LBP) tend to exhibit movement control impairments [1] and altered postural control [2] compared to healthy individuals. The Active Hip Abduction (AHAbd) test is a sensitive measure of lumbopelvic control which is unique in that it is performed in an inherently unstable side-lying position [3]. Reduced lumbopelvic control (higher AHAbd test scores) has been shown to be associated with transient LBP development during prolonged standing and has been postulated to be associated with decreased trunk control during an upright posture [3]. Further, alterations in postural balance have been observed in individuals with LBP during several postural balance tests including single [4] and double-support standing [5]. As optimal lumbopelvic control is critical to postural balance during human locomotion, understanding the association between lumbopelvic control and upright postural balance may have clear and important implications.

Aim: This study aims to be the first to examine the association between lumbopelvic control assessed in a posturally unstable position and standing postural balance.

Methods: Thirty participants (15 males and 15 females) asymptomatic for LBP will be recruited from a university population. Participants will complete the AHAbd test, Sharpened Romberg test (SRT) and the One-Leg Standing test (OLST) bilaterally. During the AHAbd test, participants will perform a single active abduction of the hip keeping the knee extended and the lower limb aligned with the trunk, while maintaining the frontal plane alignment of the pelvis [3]. To perform the SRT, participants will stand in a tandem heel-to-toe position with their arms folded across their chest for a maximum time of 30 s. The OLST will require participants to maintain their balance while standing freely on one leg for a maximum time of 30 s. Muscle activity of selected trunk and lower extremity muscles will be recorded during the performance of the AHAbd test. This test will be videotaped to verify the scores (0 = no loss of pelvis frontal plane position to 3 = severe loss of pelvis frontal plane position) post-collection. Muscle activity, kinetic and kinematic measures will be recorded as participants perform the standing postural balance tests on a single force platform. Measures of perceived discomfort will be assessed using a visual analogue scale.

Expected Results: Reduced lumbopelvic control during the AHAbd test may be associated with impairments in postural balance during the SRT, OLST, and transient LBP development. It is hypothesized that individuals with reduced lumbopelvic control (higher AHAbd test score) will exhibit an altered hip motor control strategy (i.e. bilateral gluteus medius co-activation; reduced hip postural control strategy) and poorer performance (less constrained centre of pressure and more variable GRF) during the SRT and OLST relative to individuals with more optimal lumbopelvic control. The significance of this research lies in its exploration of the relationship between two functionally important measures which are critical to human locomotion, lumbopelvic control and upright postural balance. By examining these measures in asymptomatic individuals, movement and motor control impairments may help to identify a sub-clinical group (i.e. transient LBP developers) and thus inform LBP prevention strategies in a clinical and/or exercise setting.

References:
[1] O'Sullivan. (2005) Manual Therapy 10 (4): 242-55. [2] della Volpe. (2006) Gait & Posture 24(3): 349-55. [3] Nelson-Wong et al. (2009) JOSPT 39 (9): 649-57. [4] Luoto et al. (1998) Spine 23 (19): 2081-90. [5] Brumagne et al. (2008) Eur Spine J 17:1177–84.

CHARACTERIZING SIGNAL PROPERTIES OF THE CHANNELING PORTION OF PEDICLE SCREW INSERTION

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Introduction: Geometric deformities observed in idiopathic scoliosis are very complex, and introduce unique challenges to surgical instrumentation of the spine. The surgical procedure involves free hand channeling of a pilot hold to aid pedicle screw insertion, followed by lateral translation and de-rotation of the spine, and finally segmental normalization. While the procedure challenging in its entirety, the free-hand channeling portion is particularly complex and risky for neurovascular complications. As a result it requires a high level of skill and has a high learning curve for orthopaedic residents and fellows to adequately perform (80 screws before satisfactory proficiency). There is a significant need for a safe training environment such as a surgery simulator. The purpose of this work is to collect kinesthetic data from the free-hand channeling portion of pedicle screw insertion to use as inputs to the design of a surgical simulator.

Methods: A surgical spine probe used to free-hand channel the pedical screw pilot hole was instrumented with 6-axis load cell (Mini45, AMTI, Maine, USA) to capture forces and moments in the x-, y-, and z-axes at the probe tip. Free-hand channeling was performed on the bilateral pedicles of T3 to T12 cadaveric vertebrae by an orthopaedic surgeon (RZ) who specializes in surgical instrumentation of the scoliotic spine. Motion capture markers were also attached to the operating table and the cadaver for reference and to the surgical probe to capture the movement of the probe relative to the vertebral body.

Results: Data has been collected from two cadavers. We have preliminarily analyzed the Fz and Mz signals from the load cell in the T6 and T12 vertebrae and they are illustrated in Figure 1. Translational amplitude (Fz) was -171 N and -206 N for the T6 and T12 vertebrae, respectively. The frequency of the Mz data was 2 Hz for both vertebrae at a peak amplitude of 0.14 Nm for T6 and 0.13 for T12 vertebra. Analysis is ongoing and will be focused on identifying changing signal characteristics with depth of the surgical probe.

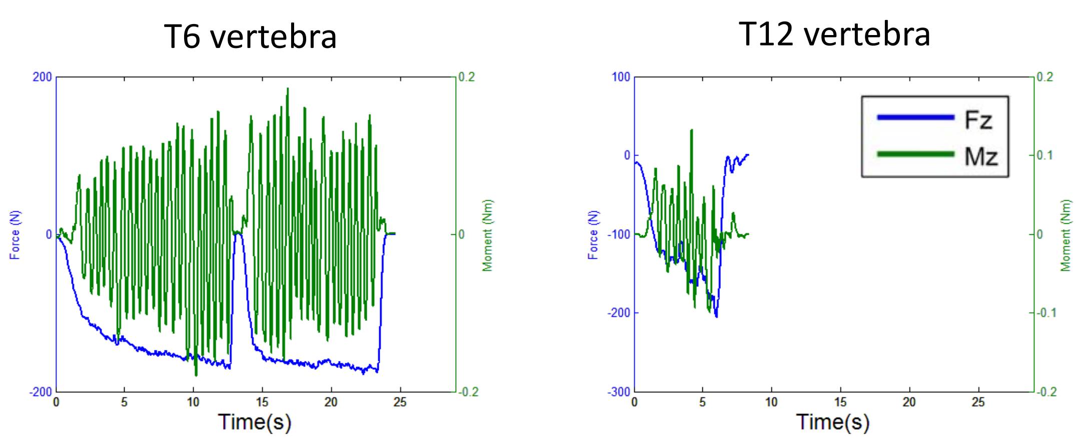

Figure 1: Tranlational force (Fz) and moment about the z-axis (Mz) for the T6 and T12 vertebrae

Discussion and Conclusions: The project is not at the point to make any conclusions, however with additional data and more analysis the aim is to identify signal characteristics for each vertebra relative to the probes position in the pedicle.

EVALUATION OF EXERCISE REHABILITATION IN PERSONS WITH SPINAL CORD INJURY

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[1]School of Physical and Health Education, Nipissing University, North Bay, ON

Introduction: Those affected with a spinal cord injury (SCI) will be burdened with loss of quality of life and large financial costs. These costs can range anywhere from $1.5 to $3 million dollars throughout their lifetime [1]. Determining if increases in range of motion (ROM) correlate positively with increases in self-efficacy (SE) may demonstrate the importance of incorporating SE practices within a rehabilitation program. Furthermore, with an improvement in rehabilitation programming, overall costs may decrease due to less time spent in an inpatient facility.

Aim: The primary aim of our study is to assess the effectiveness of a type of exercise based rehabilitation on ROM and SE in persons with SCI. A secondary aim is to compare the results of the SCI group to a group of healthy individuals that do not have a SCI.

Method: We tested an intervention group (IG) of 8 participants with SCI (1F, 7M), who were over the age of 18. Each participant was recruited from the Walk it Off Spinal Cord Injury Centre in Newmarket, a facility specialized in SCI exercise rehabilitation. Clients at the facility performed activities involving core strength, repetitive weight-bearing, arm ergometry and ambulation as part of their treatment. We tested a second group (G2) of 10 healthy university-aged participants (5F, 5M). IG and G2 were tested on ROM of their shoulder and ankle joint. Shoulder movements included; extension, abduction and flexion. Ankle movements included; plantar flexion and dorsi flexion. Each participant was asked to perform each movement 10 times as quickly and as controlled as they could. Movements were assessed by tracking the 6 degrees of freedom of their upper arm relative to their acromion process and their foot relative to their tibia (Ascension Technology Corporation, Shelburne, VT, USA). The IG was tested twice, before and after their 2-month exercise program, whereas the G2 only had 1 round of testing. The dependent variables to be analyzed are the mean and standard deviation of ROM at both joints. The IG was also asked to complete a questionnaire pre- and post-testing based on their SE levels (The Spinal Cord Injury Exercise Self-Efficacy Scale) [2]. Pre-post ROM and SE scores will be analyzed in the IG group using paired t-tests, whereas ROM scores will be compared between the IG and G2 using independent t-tests.

Expected Results: We expect to see significant improvements in ROM and SE in the IG participants that attended the exercise rehabilitation program. Furthermore we expect to find that the ROM during the post-testing in the IG will be closer to the G2 than in the pretest.

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SHOULDER AND LOW BACK LOADING IN CASHIERS; WHAT ARE THE CRITICAL CONTRIBUTING FACTORS? A LABORATORY STUDY

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Introduction: Cashiers commonly report musculoskeletal discomfort in the shoulder, neck and upper extremities [1]. Awkward and static postures, task repetition, insufficient rest, and customer demand fluctuations contribute to a workplace with injury risk [2]. The advent of enviropackaging has resulted in an increase of shopping bag weight from ~10lbs for plastic bags, to 28-38lbs for environmental bags (depending on bag size) [3]. The influence of new packaging and its interaction with existing workstation geometry and work pace has limited evaluation, particularly for upper extremity musculoskeletal demands. Further, potential tradeoffs between the shoulder and low back in response to potentially higher loads are unclear.

Aim: To quantify physical demands at the shoulder and low back, and assess tradeoffs between the shoulder and low back, while performing various grocery packaging cashier tasks in several simulated workstation configurations.

Methods: An adjustable workstation will be constructed with a conveyer and bagging area to simulate that observed in a prior field study. Twenty-five experienced cashiers (12M, 13F) will perform cashier packaging tasks defined by intensity of effort (6 or 20 items), type of packaging (plastic bags, customer supplied bags, and reusable bins), and workstation configuration to identify muscular and postural loads in each scenario. 3D upper body motion of the wrist, elbow, shoulder and lumbar spine will be recorded optoelectronically (Vicon Motion Systems, Oxford, UK). Surface EMG (Noraxon, USA Inc., Arizona, USA) will be recorded bilaterally for five shoulder muscles (upper trapezius, middle trapezius, serratus anterior, anterior deltoid, and middle deltoid) and three back muscles (upper (T9) and lower erector spinae (L3), and external oblique). Postural and load data will be analyzed with the Shoulder Loading Analysis Modules [4] to determine joint angles, angular velocity, angular acceleration and moments at the shoulder and low back. EMG data will be normalized and used to create Amplitude Probability Distribution Function (APDF). For all dependent variables, repeated measures ANOVAs will be applied to identify the influence of intensity, types of packaging and workstation configuration as within participant factors. Further, tradeoffs between the back and shoulders will be assessed through quantitative assessment of joint moment demand redistribution across task scenarios.

Expected Results: Packaging type, intensity, and workstation configuration are all anticipated to influence the physical exposure metrics; however, the extent of these influences is unknown. Preferred workstations and types of exposure will be those that lower mechanical joint and muscular demands and promote neutral postures. From the consolidated findings, workstation layout recommendations will be made to mitigate potentially hazardous exposures.

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DOES ISOMETRIC STRENGTH TRAINING DECREASE VALGUS ANGLE DURING A DROP-JUMP LANDING IN ELITE FEMALE VOLLEYBALL PLAYERS?

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Introduction: In women's volleyball, knee injury predominantly occurs during non-contact maneuvers such as landing tasks that are associated with high external knee loads [1]. Knee valgus deviation (KVD) loads the passive tissues that maintain the structural integrity of the tibiofemoral joint, increasing the risk for injury [4]. The ACL resists anterior tibial translation relative to the femur, which, in association with KVD, links larger valgus angles with excessive ACL strain, and hence, ACL injury [5]. During landing, muscular weakness in abduction, external rotation and extension at the hip joint are associated with higher valgus angles [3]. Isometric resistance training has been shown to produce larger strength gains, higher muscle activation levels [2], and improved activation timing [6] vs. dynamic training. However, it is not clear if isometric strengthening of these hip muscles will decrease knee valgus angle during a drop-jump landing task.

Aim: This study will determine if strengthening the gluteus maximus, gluteus medius, and hamstring muscles via isometric contractions will decrease the peak knee valgus angle in elite volleyball players during a drop-jump landing task**.**

Methods: Twenty female elite volleyball players (10 control group (CG); 10 training group (TG)), will be recruited from local clubs and university and college teams. TG participants will exhibit peak valgus knee angles of >9 degrees, as determined from a pre-screening session. Isometric muscle strength will be assessed in standardized positions before (pre-test) and after (post-test) six weeks of training (five days/week). 3D motion of the trunk and lower extremities during 15 drop-jump landings (two-footed jumps down from a 30cm box, followed by maximal block jumps) will be captured using standard marker and camera setups. Tibial accelerations and impact forces will be recorded using two tri-axial accelerometers and two force platforms, respectively.

Expected Results: Muscle strength and the peak valgus angle during the drop-jump task are expected to increase and decrease, respectively, in the TG, but no change is expected in the CG.

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THE EFFECT OF LOCAL HYDRATION ENVIRONMENT ON TEMPORAL CHANGES IN ANNULAR THICKNESS AND MASS

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Introduction: The annulus fibrosus (AF) is an avascular tissue that exchanges nutrients and waste with its surrounding environment. Hydration level has previously been shown to affect the mechanical properties of ovine functional spine units [1]. Previous research has been conducted in our lab to characterize the biaxial tensile properties of isolated porcine annulus samples at room temperature; however, hydration of the specimens was not systematically controlled [2]. The purpose of this investigation was to characterize temporal changes in mass and thickness in isolated, multilayer samples of annulus fibrosis tissue using four hydration techniques.

Methods: A total of 48 porcine anterolateral AF samples were tested from three intervertebral levels; C23, C34 and C45. Samples were tested in one of four unloaded, temperature controlled hydration environments for 120 minutes using 0.9% weight/volume saline solution including (i) in an immersed bath, (ii) misting once per hour, (iii) in a temperature and humidity controlled environment at 90% (± 5) relative humidity (RH) at 30°C (± 1) and (iv) combined misting in a 90% RH chamber at 30°C (± 1). Each sample was an average of 1.01mm (SD 0.19mm) thick and contained 3-5 lamellae from intermediate annular layers (within layers 3-8). Time-varying changes in thickness and mass were normalized to baseline values and measured at four different time points: 15; 30; 60; and 120 minutes.

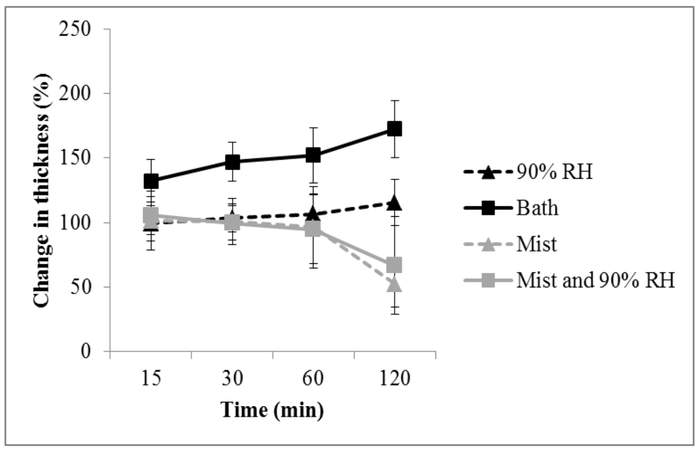

Figure 1. Percent change in annular thickness over time across hydration condition

Results & Discussion: The hydration environment method interacted with time to affect the percent change in thickness ($p \leq 0.0001$) (Figure 1) and mass ($p \leq 0.0001$) of the specimens. In the immersed bath condition, there was an average 72% (SD 22%) increase in thickness and an 81% (SD 15%) increase in mass compared to baseline values. Specimens in the misting and the combined misting with 90% RH conditions responded similarly, where specimen thicknesses were within 95% of baseline values after 60 minutes but after 120 minutes specimens became dehydrated with thickness reductions of 48% (SD 18%) and 34% (SD 38%) respectively. The 90% RH environment produced values closest to baseline of all the environments with a 15% (SD 18%) increase in thickness and a 17% (SD 16%) increase in mass after 120 minutes, respectively. The local hydration environment affects the mass and thickness of unloaded annular samples and the impact of this effect has a temporal dependence. The results of this investigation support testing porcine samples in a local environment of 30°C with a controlled humidity of 90% to maintain the mass and hydration of annular test specimens.

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EMG CHANGES OF THE FOREARM EXTENSOR MUSCLES AT DIFFERENT POSTURES

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Introduction: Although lateral epicondylitis (LE) is prevalent in only 1-3% of the general population, this prevalence increases to 15% of the working population [1]. In Washington State alone, direct compensation was reported to be twelve million dollars per year, particularly due to the number of lost workdays per employee affected [2]. Among the identified work-related risk factors, a combination of forceful hand exertions combined with repetitive pronation and supination of the forearm is strongly associated with LE [1].

Aim: This study aims to better understand the interactions of the muscles that insert into the common extensor tendon, which attaches to the lateral epicondyle, during pronation and supination. We will compare EMG of extensor carpi radialis brevis (ECRB), extensor digitorum communis (EDC), and extensor carpi ulnaris (ECU) at different forearm postures for forceful handgrips with the same handgrip force, gravity response, wrist and elbow postures.

Methods: Sixteen participants (8 male, 8 female) with no history of injury to the dominant arm will be recruited. Participants will be positioned such that their forearm will be vertical, elbow flexed at 90° and their wrist fixed in a neutral posture. They will be asked to grasp a hand grip dyanomometer (Digital Analyser, MIE medical Research LTD, Leeds, Yorkshire, UK) at a force level equivalent to 75% of their maximum recorded with their forearm in a neutral posture. EMG (DataLOG W4X8, Biometrics LTD, Cwmfelinfach, Gwent, UK) will be collected from the ECRB, ECU, and EDC while grasping in each of three forearm postures (pronation, supination, and neutral). Raw EMG and wrist angle will be collected at 2000Hz. Full wave rectified and low pass filtered at 3Hz EMG and wrist angles will then be averaged over the duration of constant grasp force.

Expected Results: Given the external load and posture at the wrist is held constant, the extensor and radial/ulnar deviation moments at the wrist will be similar in all three forearm postures suggesting the relationship between the three muscles would be constant. However, variable changes in the length of the muscles in both direction and magnitude as a result of pronation and supination should alter the aforementioned relationship, suggesting a source for friction between the tendons of the three muscles. It is expected that the ECRB will respond in an opposite direction from the other two muscles.

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IDENTIFYING MEASURES OF FATIGUE – THE CRE-MSD TORONTO WORKSHOP

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Introduction: The measurement and quantification of fatigue may play a significant role in reducing the extent of fatigue at the workplace [1]. However, since fatigue manifests in various forms in various domains, a single test to measure a single function might not be a feasible method [2]. A workshop was convened to identify and evaluate fatigue measures from different research disciplines and perspectives. The aim of this workshop was to identify a set of fatigue measures that are practical, reliable, sensitive, and valid when measuring fatigue in the workplace.

Methods: Fourteen researchers from four countries (Canada, United States of America, Sweden, Netherlands) were invited to participate in a one-day workshop. Researchers represented nine disciplines and all had an established research interest in fatigue. Through a series of breakout sessions and full group meetings, workshop participants were asked to: (1) Identify potential outcomes and/or effects of fatigue based on performance and quality, injury and disorders, illness and wellness, and discomfort, (2) Identify potential causes and mechanisms related to these outcomes and effects, (3) Identify fatigue measures and detection methods to monitor causes and mechanisms, and (4) Assess these measures and detection methods for their utility in both laboratory and field settings.

Results: Workshop findings were reported with a process chart diagram, documenting links between outcomes, mechanisms, and measures. These relationships were then summarized to identify associations between fatigue measures and outcomes of performance and quality, injury and disorders, illness and wellness, and discomfort. Fifty-eight measures were identified and assessed for their reliability, validity, and practicality using a 3-point Likert scale (high, medium, low). Maximum voluntary contractions, questionnaires, ratings of perceived exertion/discomfort, and Borg scales were highly regarded in laboratory and field settings.

Discussion and Conclusions: Four measures were recommended for both laboratory and field settings, two of which addressed all four outcomes (questionnaires and ratings of perceived exertion or discomfort). There were no measures that were rated “low” (i.e., not recommended in both laboratory and field settings), but three measures were deemed “medium-low” in the lab (e.g., blood pressure, electrodermal responses, MMG frequency), and twenty-four were assessed as “low” in the field. However, results serve as a guide and it remains the researcher’s discretion to select measures to address multiple fatigue domains or outcomes and to satisfy context-based practicality.

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NEUROMECHANICAL CONTROL OF DUAL-TASKING

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Introduction: A dual-task paradigm, in which individuals simultaneously perform a cognitive and postural task, is often used to examine how attentional resources are shared between two tasks [1]. When an individual's attention is focused towards the cognitive task, performance on the postural task is often affected. To examine how individuals compensate for this greater postural instability, researchers have evoked the Hoffmann reflex (H-reflex) to assess the neural excitability within the spinal cord [2]. This research has demonstrated a decreased spinal excitability in dual-task compared to single-task performance [3]. Given that dual-task performance requires access to a finite amount of attentional resources, it would be reasonable to expect further reductions in spinal excitability as more difficult dual-tasks are performed.

Aim: To examine how spinal excitability changes during dual-task performance and whether this response is altered based on the difficulty of the cognitive or postural tasks.

Methods: Thirty adults will perform nine dual-task conditions, with each requiring the simultaneous performance of a cognitive and a balance task. The cognitive task will be a modified form of *Guitar Hero*, where participants will use the guitar controller to respond to moving targets on a computer monitor. For the balance task, participants will try to stand upright on a stability platform that can tilt in the sagittal plane. A combination of changes in cognitive and postural task difficulty will create the nine dual-task conditions. Cognitive task difficulty (three levels) will be increased through manipulation of the order in which the buttons correspond to the targets while balance task difficulty (three levels) will be altered by making the platform more unstable (i.e., removing resistance bands that oppose platform tilting). To examine whether spinal excitability is scaled to the difficulty of the dual-task condition, H-reflexes will be elicited in the right soleus muscle through submaximal (~10% of maximum muscle response) transcutaneous electrical stimulation of the posterior tibial nerve. The peak-to-peak H-reflex amplitude to each electrical stimulus will be determined and then averaged for each condition.

Expected Results: It is hypothesized that spinal excitability will scale to the difficulty of the dual task condition, with the soleus H-reflex amplitude decreasing as the difficulty of the dual task increases. This would demonstrate a way in which the central nervous system responds to a reduction in the availability of attentional resources for postural control. By reducing neural excitability at the spinal level, this may prevent over-corrections of postural responses when a loss of balance is experienced and thereby minimize postural instability.

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CAN PLANTAR CUTANEOUS STIMULATION VIA VIBRATION FACILITATE WALKING/STANDING IN INDIVIDUALS WITH AN INCOMPLETE SPINAL CORD INJURY?

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Introduction: Although locomotion is possible without sensory input from the periphery, movement regulation relies on the spinal integration of sensory signals [1]. Diminished pathways are associated with decreased muscle control and can be detrimental to an individual's walking and standing patterns. This is especially important to consider for individuals with spinal cord injuries who may benefit from an increase in sensory signal integration. Several studies have demonstrated that a vibratory stimulus applied to the soles of the feet can stimulate sensory input to the spinal cord. Results from such studies indicate increased muscle activation in the lower limbs [2]. Applying this type of research to spinal cord injured individuals may be able to assist in designing a rehabilitation program to facilitate an increase in muscle activity that could contribute to improved muscle utilization and potentially improved standing balance and walking within their everyday lives.

Aim: The aim of this study is to establish if the use of plantar cutaneous stimulation (via vibration) has an influence on muscle activity patterns during standing and walking in healthy young adults. The overall objective of this study is to investigate whether or not a vibrating insole will facilitate muscular activation. The hope is that in the future, this research can help to create a vibrating insole for spinal cord injury rehabilitation patients that will elicit an increase in controlled balance and walking techniques.

Methods: Non-spinal cord injured individuals (approx. n=8) will be recruited from Laurier. Participants will perform three tasks under three different conditions. The three tasks include a quiet standing trial, an overground stepping trial and a treadmill stepping trial. Each of these trials will be performed on a force plate in order to measure the participant's forces and center of pressure. The conditions include no vibratory stimulation, submaximal vibratory stimulation (90% of threshold) and supramaximal vibratory stimulation (three times threshold). Muscle activity will be measured via EMG (Bortec, Calgary, AB). Identical testing will be conducted on 8-10 spinal cord injured individuals once testing at Laurier is concluded.

Expected Results: Results are expected to demonstrate an increase in muscle activation of the participant's lower limbs when experiencing plantar cutaneous vibratory stimulation. Individuals with an incomplete spinal cord injury will also experience muscle activation as a result of this increased sensory input from the periphery. When comparing the different types of vibration however, it is hypothesized that submaximal vibratory stimulation will elicit a greater muscle response than that produced by supramaximal stimulation.

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INFLUENCE OF INPUT DEVICE, DESK CONFIGURATION, AND TASK ON SPINE KINEMATICS

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Introduction: The use of tablets is growing exponentially each year with 17 million units sold in 2010 and a forecasted 320 million to be sold in 2015[1]. Guidelines for the usage of these products have not yet been developed. Slanted desks have been recommended as an aid to reduce flexion and associated tension in the neck[2]. Examining the relationship between cervical and lumbar spine curvature during tablet use may be of interest as there may be a correlation between the two to maintain visual distance[2]. The purpose of this study was to analyze the changes in kinematics in the lumbar and cervical spine when interacting with either a desktop computer or tablet, on a sloped or horizontal work surface.

Methods: Fourteen participants (6 male and 8 female) volunteered for this study. Three-dimensional kinematics collected for the cervical and lumbar spine were sampled at 32 Hz using a motion capture system (Optotrak Certus, NDI, Waterloo, Canada). Participants sat for an hour at a hybrid sit-stand workstation with a work surface that could slope to 15° from horizontal (Focal Upright Furniture, New York, USA). The hour was separated into four randomized 15-min conditions: horizontal-computer (HC), horizontal-tablet (HT), sloped-computer (SC), and sloped-tablet (ST). Within each condition, participants completed three 5-min tasks: reading (READ), emailing (MAIL) and filling out a form (FORM). Cervical and lumbar median angles and range of motion (10^{th} to 90^{th}%ile angles) were extracted from amplitude probability distribution functions (APDF) performed on the angle data.

Results: An interaction between device and task (p= 0.0061) was found for lumbar spine angle (Figure 1). Lumbar spine angle was not affected by the device for MAIL (p=0.7263), but was more flexed when using the computer for READ (p<0.0001) and FORM (p=0.0106). More neck flexion was quantified when using a tablet on a horizontal versus a sloped surface (p=0.0228).

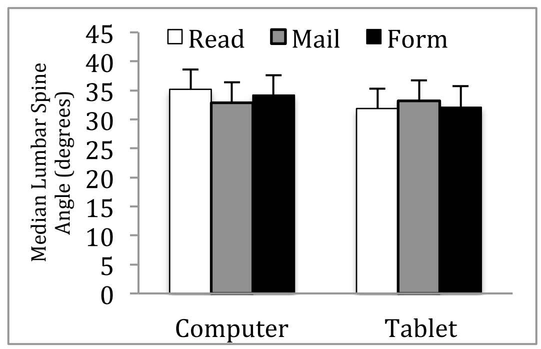

Figure 1. Median lumbar spine angles between device and task.

Discussion and Conclusions: Both READ and FORM tasks caused an increase in lumbar flexion while using a computer compared to the tablet, likely because the tablet screen could be moved closer to the participant while they were using it. If reading is the primary task performed it should be done using a computer with the monitor positioned to produce minimal neck flexion, which is associated with neck discomfort and musculoskeletal disorders[3]. If only a tablet is supplied to do the reading, a sloped desk should be used or an adjustable tablet monitor arm should be provided to place the tablet in a similar position as a desktop monitor.

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Table 1. Neck median and range angles from the APDF when reading in sloped or horizontal desk positions (in degrees – mean (standard error))

	Median Horizontal	Range Horizontal	Median Sloped	Range Sloped
Computer	6.9 (2.9)	10.3 (1.9)	5.5 (2.7)	13.8 (2.7)
Tablet	26.6 (2.5)	16.9 (4.9)	22.7 (2.4)	10.4 (1.6)

IS KNEE OSTEOARTHRITIS A RISK FACTOR FOR NON-SPECIFIC LOW BACK PAIN DURING LIFTING?

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Introduction: Repeated lifting in the workplace can greatly increase the risk of developing low back disorders (1). The whole body is involved in lifting; but the low back (L5/S1) and the knees are the most loaded joints (1). Degenerative changes in the knee, such as articular cartilage loss and quadriceps muscle weakness in knee osteoarthritis (KOA), are associated with loss of knee extension. This knee mal-alignment may affect spinal posture by tightening hamstrings, thereby reducing lumbar lordosis. Reduced lumbar lordosis increases intra-discal pressure and is a risk factor of low back pain (LBP). The link between LBP and knee pain through alterations in alignment of the lower limb and low back has been described as the "knee-spine syndrome" in the literature (2). Due to painful restrictions in knee range and strength in those with knee osteo-arthritis (KOA) (3), it is possible that workers with KOA will choose lifting postures that make their backs vulnerable to developing non-specific LBP.

Aim: The purpose of this study is to compare the L5/S1 moments during lifting between working age adults with and without painful KOA.

Methods: Kinematic and kinetic analysis of the knees, hips and trunk will be performed in 10 participants with KOA (age- 45 to 65 years) and 10 age-matched controls. Participants will be asked to perform free style lifting followed by squat lifting with 4 different masses (0, 5, 10 and 12.5 kg) in a random order (Table 1). Kinematic data will be recorded during the lifts using 3 existing banks of Optotrak Certus cameras (Northern Digital Inc., Waterloo, ON), by creating an 8-segment rigid link model (trunk, pelvis, bilateral thigh, shank and foot). Kinetic data will be recorded using 4 existing in-floor platforms (AMTI, Newton, MA) positioned under each foot. These data will be analyzed in Visual 3D (C-motion Inc, Germantown, MD). The outcome variables of interest will be the 3D joint moments (peak and impulse) at L5/S1, hip and knee joint, normalized to height and body mass of the participant.

Table 1: The protocol incorporates a lifting series that will vary based on (1) lifting method and (2) mass, resulting in 8 lifting conditions. Free-style lifts will be completed before squat lifts; however, mass increments will be presented in random order.

	Mass Increments (Randomized) →			
Free-Style	0 kg	5 kg	10 kg	12.5 kg
Leg-lift	0 kg	5 kg	10 kg	12.5 kg

Expected Results: We hypothesize that participants with painful KOA will adopt a modified lifting pattern that unloads the knee and increases loads on the spine compared to age and sex-matched controls. We expect increased L5/S1 knee moment in participants with knee pain. We also expect that the L5/S1 extensor moment would increase with the severity of knee pain.

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THE ROLE OF PLANTAR CUTANEOUS MECHANORECEPTORS DURING GAIT

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Introduction: This paper investigates the relationship between cutaneous mechanoreceptors in the plantar surface (sole) of the foot, and muscle activation in the foot and leg. A direct coupling between individual cutaneous receptors and muscle fibres in the leg has been observed [1]. However, this relationship has not yet been observed under reduction and facilitation of plantar sensation.

Aim: The purpose of this research to quantify a relationship between plantar pressure changes and subsequent muscle activation (either generated or inhibited) of the lower leg during gait tasks under reduced, normal and facilitated plantar sensation.

Methods: This project will focus on two populations: young adults (18-35) and older adults (65-80). Each participant will be equipped with foot pressure sensors (Medilogic, Germany), electromyography electrodes (Bortec, Calgary, AB) on the lower leg muscles, and OptoTRAK (Northern Digital, Inc., Waterloo, ON) markers to collect data pertaining to foot pressure patterns, leg muscle activity, and position in space, respectively. Fitted with standard footwear, all participants will complete trails including quiet standing, one-legged stance, cross-over stepping, and unexpected gait termination. Additionally, adults aged 18-35 years only will complete unexpected slipping trials. Facilitated plantar sensation will be achieved through the use of specially designed insoles with a raise ridge (3-4mm) around the perimeter of the insole (BalancePro™, http://www.balancepro.ca) [2]. Reduced sensation will be achieved, only in the young adults, by the use of an ice bath (1-2 inches of water at 1-2 degrees Celsius) on only the soles of their feet [3]. Analysis will involve muscle activation timing, center of mass, base of support and center of pressure. This research will provide insight into the role of plantar-surface sensation in modulating activation of muscles in the leg. This will be important for older adults who experience reduced plantar sensation with age [4]; specifically, this research will contribute to shoe design, orthoses and other assistive devices for populations with reduced plantar sensation.

Expected Results: This study will provide insight into plantar-surface pressure changes that change the lower leg muscle activity during human gait. It will also provide information about any relationship that may exist between the location of pressure and the activation of muscle activity in the lower limb (and its effects on balance) under varying conditions of plantar sensation.

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INVESTIGATING THE EFFECTS OF BALANCE, PLANTAR PRESSURE AND CUTANEOUS SENSITIVITY IN DIABETIC INDIVIDUALS DURING STAIR GAIT

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Introduction: Peripheral neuropathy (PN), a dysfunction of the peripheral nerves that limit sensation of the limbs, is a result of diabetes mellitus [1]. During gait, individuals exert pressure on the plantar surface of the feet, and with PN, these increased pressures on the feet can often lead to tissue ulcerations [2]. When left untreated, ulcers become the most important risk factor for lower-extremity amputations [3]. The plantar-surface pressures during normal walking are considered mild in comparison to stair climbing, which increase as individuals ascend and descend stairs [4]. As individuals traverse the stairs, their dynamic stability is continuously active to keep them upright, however this same balance system can compromise the pressures exerted on the feet, increasing the likelihood of ulcerations [2]. When offloading strategies, such as softer insoles, re-distribute plantar pressures to reduce the risk of ulcerations, the absorbing nature of the soft insoles can further decrease plantar foot sensation of PN individuals and compromise their balance response [3]. Therefore with diabetic individuals who have diagnosed peripheral neuropathy in the foot, do insoles that proportionately offload pressure and promote stability effectively reduce the risk of foot ulcers and falling?

Aim: The proposed research will look at pressure offloading and dynamic stability of individuals with diabetes (PN), with respect to insole cushioning. The aim of the research will be to 1) quantify stair gait foot pressures and subsequent dynamic stability of individuals with PN, 2) compare the effects (pressure and balance) of varying levels of insole hardnesses, 3) Develop guidelines and assistive devices to optimize ulceration prevention and balance stability in PN.

Methods: The study will look at adults with diagnosed PN (without ulcerations); and a healthy age-matched control group. Participants will ascend and descend stairs and will be instrumented with pressure insoles to measure peak pressures and rate of change of pressure. Motion will be captured to record the individual’s centre of mass and their foot placement to evaluate dynamic stability measures. Similar footwear containing interchangeable levels of insole hardnesses will be placed under the pressure insole for each participant during stair gait. Dynamic balance response and pressure measurements will be recorded during simulation of normal stair gait.

Expected Results: Individuals with PN will demonstrate greater instability and peak pressures during stair gait due to their diminished plantar sensations. Soft insoles (20% less dense than EVA foam) will reduce peak pressures and decrease stability during stair gait. There will be an optimal level of insole hardness that will provide appropriate stability and limit the plantar pressures that could cause ulceration.

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EVALUATING THE EFFECT OF REST BREAKS ON PRODUCTIVITY, DISCOMFORT, AND TRUNK POSTURAL CONTROL DURING PROLONGED SEATED TYPING

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Introduction: Low back pain (LBP) is a common complaint among seated sedentary workers and contributes to workplace absenteeism [1]. Standing or walking rest breaks have been suggested as an administrative control to reduce LBP in this population. However, the ideal length or frequency of rest breaks is not well established, nor do we understand the underlying mechanisms that may explain why these intermittent breaks are beneficial. The purpose of this study is to measure self-reported discomfort, productivity, and trunk muscle activation during prolonged seated computer work when using four different rest break schedules. Additionally, we aim to measure the mechanical properties of the trunk before and after each prolonged seated condition to determine if the length or frequency of breaks alters the mechanical properties of the trunk.

Methods: Twenty healthy volunteers will be recruited to complete 60 minutes of typing (transcribing) in each of four different rest break schedules. The conditions will include 60 minutes of typing interspersed with: Condition A – no rest; Condition B – 5 minutes of rest every 30 minutes; Condition C – 2.5 minutes of rest every 15 minutes; and Condition D – 50 seconds of rest every 5 minutes. A Visual Analog Scale (VAS) will be used to collect low back discomfort data and surface EMG will be recorded bilaterally from the lumbar erector spinae. These data will be recorded at the beginning and end of the trial and at 10-minute intervals during the trial. Productivity will be evaluated by counting the number of typos and calculating average number of words typed per minute. Participants will complete a NASA-TLX at the conclusion of each condition to evaluate their perceptions of workload in each condition. To further reveal potential mechanisms that may help explain any rest break related differences in VAS or EMG measures, mechanical properties of the trunk will be evaluated prior to and following each condition using methods described by Hodges et al. [2]. Two-factor (Time X Condition) repeated measures ANOVAs will be used to detect differences in VAS and EMG measures, and trunk mechanical properties. A one-factor (condition) repeated measures ANOVA will be used to detect differences in the productivity and perceived workload measures.

Expected Results: We expect VAS scores (0 - no LBP; 10 worst LBP ever) and lumbar erector spinae activation to increase over time, stratified lowest to highest through conditions D to C to B to A; trunk stiffness to decrease over time, stratified from lowest to highest through conditions A to B to C to D; average words typed per minute and typos not to change across conditions; and participants to favour conditions B and C. These results are predicted based on the hypothesis that VAS scores and lumbar erector spinae activation are positively associated, and inversely related to trunk stiffness. Work productivity is not expected to change given that total work time is the same across conditions. Participants are expected to favour conditions B and C because condition A may be cognitively fatiguing and condition D may interrupt work flow. Based on the results from the current study, it is expected that recommendations can be made for optimal rest-break schedules for sedentary seated work.

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ASSOCIATION BETWEEN SPASTICITY AND BALANCE IMPAIRMENTS IN PERSONS POST-STROKE

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Introduction: Although balance impairment and spasticity are common problems in persons post-stroke, the relationship between spasticity and balance impairment is not clearly understood. In this study, we investigated the association between spasticity and balance impairment to understand if spasticity can contribute to physical and psychosocial aspects of balance control in persons post-stroke.

Methods: Fifteen patients with stroke and spasticity completed the Activities Balance Confidence Scale (ABC) as a measure of patients' balance self-efficacy, and the Berg Balance Scale (BBS) to assess functional balance performance. Total spasticity levels in the upper limbs (UL) and lower limbs (LL), and number of muscle groups with spasticity in the UL and LL were gathered from Modified Ashworth Scale (MAS) scores from patient charts. Spearman's rho was used to study the correlation between spasticity and balance measures.

Results: Significant negative correlations between total upper limb MAS Score and ABC (rho= -0.50; $p<0.05$) and BBS (rho= -0.52; $p<0.05$) were found. Similarly, significant negative correlations between number of muscle groups with spasticity in the upper limbs and ABC (rho= -0.58; $p<0.05$) and BBS (rho= -0.51; $p<0.05$) were found. Total lower limb MAS scores and number of muscle groups with spasticity in the lower limbs both showed non-significant positive correlations with the ABC (rho= 0.31; p= 0.13) and (rho= 0.29; p= 0.15), and with the BBS (rho= 0.15; p= 0.29) and (rho= 0.17; p= 0.27) respectively.

Conclusion: The results suggest that upper limb spasticity in patients post-stroke, in terms of total spasticity level and number of muscle groups with spasticity, contributes to balance impairment and balance confidence. Upper limb spasticity should be considered when clinically evaluating falls risk for patients post-stroke.

FILTERING REVISITED: CUTOFF FREQUENCY EFFECTS ON MUSCULOSKELETAL SIMULATIONS

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Introduction: Musculoskeletal simulations of high impact movements such as running and jumping are important in understanding the biomechanics of injuries which occur in sports. Previous research has shown that filtering marker position and force plate data with non-matched filter cutoffs can result in significant artefacts in calculation of joint moments [1]. Filtering parameters for motion data with large impact peaks in the ground reaction force affects inverse dynamics; however, it is not known how filtering impacts musculoskeletal simulations. The purpose of this study was to determine the effects of filter cutoff frequency on lower extremity muscle force simulations during jump-landing.

Methods: Five participants performed a maximum height, single leg jump-landing. A three dimensional motion capture system recorded marker position data and a single force platform recorded ground reaction forces. The kinematic and kinetic data for each trial was filtered with a dual pass Butterworth filter at four combination cutoff frequencies: 10Hz markers, 10Hz force (10-10); 10-50; 15-15; 15-50. Musculoskeletal simulations from 100ms prior to landing to 300ms after landing were performed in OpenSim using Computed Muscle Control algorithms.

Results: The hip and knee joint moments demonstrated significant differences in peak moments between filtering conditions ($p<0.05$), with the unmatched trials showing large fluctuations at impact. Peak muscle forces were significantly different for the quadriceps, hamstrings, and gastrocnemius ($p<0.05$), with higher forces observed in the unmatched (10-50, 15-50) conditions than in the matched (10-10, 15-15) conditions. During the simulation, if the muscles were not able to reproduce the necessary torque at each joint then an additional ‘reserve’ (non-physiologic) torque was applied to keep the model stable. Reserve torques were seen primarily at the time of the fluctuations seen in the inverse dynamics and were significantly less ($p<.05$) on the matched than unmatched conditions.

Discussion and Conclusions: The process of filtering motion data affected segment accelerations and ground reaction forces which led to variations in simulated muscle forces and reserve torques. Unmatched filter conditions with higher force cutoffs produce artifacts in the joint moments and larger forces which may not be physiologic. It is suggested that matched filter cutoffs should be used to avoid potential artifacts in inverse dynamics and simulation results.

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ACTIVITIES OF DAILY LIVING FOR UNILATERAL TRANSFEMORAL AMPUTEES: AN EVALUATION OF KINEMATICS, KINETICS, AND TRUNK MUSCLE ACTIVITY

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Introduction: The existing research on the movement adaptations of transfemoral amputees has primarily focused on the kinematics and kinetics of the lower limbs. Given the high incidence of low back pain among lower limb amputees [1], the trunk is an important aspect of amputee movement. Additionally, decreased quadriceps force has been associated with compensatory trunk muscle activity [2]. Transfemoral amputees do not have muscles crossing the knee joint and, as such, much of the movement associated with walking and other activities of daily living would be produced by the muscle of the hip and trunk. While research into various types of transfemoral ambulation is well established, some other activities of daily living are not as well represented.

Aim: The purpose of this research is to investigate the biomechanical compensatory strategies employed by unilateral transfemoral amputees for five activities of daily living. It will focus on kinematics and kinetics of the lower limb and trunk, as well as muscle activity of the hip and trunk. Data from the legs, pelvis, and trunk will be consolidated to establish a more complete and contextualized understanding of transfemoral amputee movement.

Methods: A group of mobile unilateral transfemoral amputees with no confounding comorbidities (eg. spastic hemiplegia), will be paired with an age, sex, height, weight, and health-matched control group. Data will be recorded over five tasks: level, ramp, and stair walking, a sit-to-stand movement, and a simulated door opening activity. Kinematics and kinetics of the legs and trunk will be recorded using a six-sensor Optotrak Certus (NDI, Waterloo, ON) active-marker motion capture system and a staggered cluster of four force plates. Foot, shank, thigh, pelvis, and trunk segments will be defined. Muscle activity will be recorded bilaterally by pairs of surface EMG electrodes, recording the rectus abdominus, internal and external obliques, lumbar erector spinae, latissimus dorsi, superior lumbar multifidus, and gluteus maximus muscles.

Expected Results: In general, it is expected that transfemoral amputees will exhibit increased lateral trunk flexion and pelvic tilt compared to the control group. They may also display an increased back and hip extensor, and abdominal muscle activity on the side contralateral to the prosthesis. A decreased prosthetic hip range of motion is expected, while asymmetry in transfemoral amputees will be increased as compared to the control group; especially in the sit-to-stand and stair ambulation tasks.

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THE INTER-RATER RELIABILITY OF A NOVEL BATTERY OF RANGE-OF-MOTION TESTS

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Introduction: Range of motion (RoM) deficits have been identified as a risk factor for injury in highly trained groups such as athletes, firefighters and military personnel (1,2). Specifically, it has been suggested that individuals with either limited or asymmetrical RoM are at a greater risk of sustaining injuries than are individuals without RoM limitations or bilateral asymmetries. To gain insight into causal mechanisms between RoM deficits and injury risk, it may be necessary to assess the uni- and multi-articular constraints that limit a joint's biomechanical degrees-of-freedom. To our knowledge, an assessment battery of this nature has not been presented in the literature. We hypothesize that a novel RoM assessment that examines these constraints throughout the kinetic chain may assist to uncover specific deficits that are restricting the execution of closed chain whole-body movements in occupation or sport.

Aim: To examine the inter-rater reliability of a novel battery of RoM tests that assesses the uni- and multi-articular constraints of the metatarsophalangeal, ankle, knee, hip and shoulder joints.

Methods: Thirty-four volunteers (17 men, 17 women) without any musculoskeletal disorders or pain between 18-35 years of age will be recruited. Participants will attend one 2.5 hour session wherein their RoM will be examined with a battery of mobility tests. Within this single session, the assessment will be administered three times by different clinicians, each lasting approximately 30 minutes. Thirty minutes of passive recovery will be provided between each assessment. Exposure to the three clinicians will be randomized, but the order of RoM tests will be standardized. In total, the RoM assessment will consist of 16 measurements: ankle dorsiflexion, first metatarsophalangeal joint dorsiflexion, hip extension, hip flexion, hip adduction, hip internal rotation, shoulder flexion and shoulder internal rotation (left and right side). The inter-rater reliability of each RoM test will be calculated with the intraclass correlation coefficient (ICC) using SAS (SAS, Cary, NC). ICC values greater than 0.75 will be described as having "moderate" reliability.

Expected Results: Each RoM test will have an ICC greater than 0.75 and a minimum reliability rating of "moderate". However, variability is also anticipated given the potential challenge in palpating/locating certain bony landmarks. Ultimately, the results of this investigation may assist in the development of an assessment tool that will help to guide personalized exercise recommendations for the prevention of musculoskeletal injuries.

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RELATIONSHIP BETWEEN THE STARTING ANGLE OF THIGH-CALF CONTACT AND ANTHROPOMETRIC MEASURES BETWEEN SEX AND HIGH-FLEXION ACTIVITIES

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Introduction: Many knee models for the prediction of tibiofemoral joint contact forces in high flexion neglect to account for the contact between the thigh and the calf that occurs during high-flexion activities such as kneeling and squatting[1]. This omission, some suggest, would cause musculoskeletal models to overestimate tibiofemoral joint contact forces in high-flexion[2]. Previous publications have measured thigh and calf contact characteristics, however, these studies only measured thigh-calf contact during dorsiflexion kneeling and squatting were non-discriminate about participant's sex[1,3]. This oversight may have led to incorrect assumptions in the calculation of both thigh-calf contact force and knee joint force during high-flexion activities due to noted anatomical and fat distribution pattern differences between sexes.

Objective: The objective of this investigation was to investigate the relationship between the starting angle of thigh-calf contact and anthropometric measures and to compare these relationships between high-flexion activities and sexes.

Methods: 8 healthy participants, 4 male (mean BM of 84kg ± 8.23 and mean thigh-circumference of 55cm ±3.83) and 4 female (mean BM of 62.25kg ± 8.39 and mean thigh-circumference of 50cm ±3.63) performed two high knee flexion activity trials, squatting and kneeling. Anthropometric measures such as thigh and calf circumference, height, mass and sex were taken from participants to be used in the predictive equations. Contact pressures between the thigh and the calf of the participant's dominant leg were recorded using a pressure mapping sensor (XSensor, Calgary, AB). Knee flexion angles were measured using a motion capture system Northern Digital Incorporated, Waterloo, ON). The starting angle of thigh-calf contact force was then calculated.

Results: Thigh-calf contact was initiated at a lower average flexion angle for the squatting trials for both male and female, 131.89^0 (SD 3.51) and 139.1^0 (SD 1.48) compared to kneeling, 140.08^0 (SD 2.92) and 146.32^0 (SD 2.5). Thigh-calf contact was initiated at a lower flexion angle for males, which had larger thigh-circumferences in this investigation compared to females. Differences between squatting and kneeling, for both males and females, were found to be significant (p= 0.002 and 0.0024). In addition, independent of sex, a subject's mass, thigh and calf circumference were all found to be significant for the prediction of the starting angle of thigh-calf contact during squatting (p = 0.007, 0.05 and 0.05 respectively) and kneeling (p = 0.02, 0.01 and 0.05 respectively).

Conclusions: The starting angles of thigh-calf contact obtained in this investigation were comparable to those reported previously [1]. Unlike the previous investigation, the current investigation separated participants based on sex, a variable which proved to be significant (p=0.002) and therefore should not be neglected in investigations dealing with thigh-calf contact characteristics. Although, given that there was a large difference in anthropometrics between male and female participants it remains unclear if this difference is due to sex or anthropometric measures. Further research will assess the significance of anthropometric characteristics and sex to the starting angle of thigh-calf contact as well as the magnitude and location of thigh-calf contact force during high-flexion activities in order to develop more realistic high-flexion knee models.

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INCREASING STRENGTH THROUGH THE POWER OF VISUALIZATION

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Introduction: When an individual improves their strength, there are two general mechanisms at work: muscle hypertrophy and neural adaptation [1]. These early gains in strength are primarily due to changes associated with the motor unit, including an increased recruitment, synchrony and firing rate of the unit as well as the presence of doublets [2]. Neural adaptation to exercise is an area that has received increased interest throughout the scientific world in recent years – more specifically, the mechanisms behind mental training (MT) and its applicability in rehabilitation settings [1]. In terms of rehabilitation for individuals incapable of performing physical therapy due to their impairment, MT may have the ability to improve the rehabilitation of individuals [1] and could decrease the amount of time the person would have to spend in physical therapy if strength is an issue for the individual.

Aim: The aim of this study was to see the impact of MT of the quadriceps on time to peak torque, muscular endurance and muscular strength as well as electrical activity to the muscle group as measured through electromyography (EMG).

Methods: Participants were randomly assigned to either a strength training group (STG), a mental training group (MTG) or the control group (CG). Over 3 weeks participants in the training groups underwent training 5 days per week, with all 3 groups receiving testing once per week. The movement of interest was knee extension, and the torque produced was measured by the CSMi™ Humac Cybex Norm Isokinetic Extremity System (Computer Sports Medicine Inc., Massachusetts, USA). The daily training consisted of 15 isometric maximal voluntary contractions (MVC) of the quadriceps either imagined or actual. Contractions lasted 10 seconds each, with a 20 second rest period between each repetition. Contractions were done at optimal knee angle as measured by an isokinetic test performed previously to training. To ensure the MTG was not contracting their muscles, surface electrodes were attached to the rectus femoris to measure electrical activity of the muscle.

Expected Results: Following the training protocols undertaken by each participant it is expected that the MTG and STG will have both increased significantly in all aspects of strength as well as the amount of electrical activity to the rectus femoris when compared to the control group. In addition, it is predicted that the gains seen between the MTG and STG will not differ significantly. These estimations are based on previous research conducted involving MT of other various muscle groups [3-5].

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EFFECTS OF FOOT ORTHOTICS ON SPINE KINEMATICS DURING GAIT AND KINETICS DURING FREE STYLE LIFTING

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Introduction: Studies have shown that using foot orthotics improves the alignment of ankle and knee and reduces the risk of lower limb injuries [Milgrom et al, 1985]. Various Manufacturers of foot orthotics claim that these foot orthotics are beneficial in improving posture and stabilizing the spine. However the effect of foot orthotics on activity of spinal muscle and alignment is scarcely studied so it is not clear if foot orthotics are effective in altering muscle activity of spinal muscles or if they are efficient in altering alignment of spine. Various manufactures of foot orthotics claim to reduce low back pain by altering muscle activity in region of low back but there is not much evidence of such an effect.

Objective: The primary objectives of this study were 1) to measure and compare the immediate effect of foot orthotics on spinal muscle activity and spine kinematics during walking; and 2) to measure and compare the immediate effect of foot orthotics on spinal muscle activity and spine kinetics during free style lifting.

Methods: Two sets of 10 male subjects were selected without a history of back pain or previous exposure to any kind of foot orthotics. The first set of subject were used to study the muscle activity during walking and lifting by recording the EMG data for spinal muscle. The second set of subject were used to study the linear acceleration, angular acceleration and various angles of lumbar spine during walking and lifting by recording the three dimensional kinematic data. The participants performed the walking trial and lifting trial with and without the foot orthotics.

Results: Findings suggested that there was no significant changes in spinal muscle activity or spine kinematics with the use of foot orthotics during walking trial. However there was a significant difference in the activity of left Rectus Abdominis during the lifting trial. Studies from past have demonstrated that foot orthotics alter the concentration of forces laterally during support phase of gait [Scranton et al, 1982]. Previous research has revealed that use of foot orthotics with heels lifts and bilateral lateral fore- foot wedging altered the onset of spinal and gluteal muscle during walking [Bird et al 2003].In light of these results foot orthotics could be considered to be a potential factor for altering the spine muscle activity. However the present results did not show any significant effect on alignment and angulation of spine. This could be due to the fact that the foot orthotics were used only for a short amount of time. Future study should identify effects of foot orthotics on spine muscle activity and alignment with prolonged exposure.

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Ontario Biomechanics Conference Podium Presentations
14th-16th March 2014

Podium Sessions F: Sunday 16th March 8:30am – 9:20am

Podium Session	Presenter	Title
F: Methods, Instrumentation, Analysis, Modelling II Sunday 16th March 8:30am – 9:20pm	Chris Bailey	An accelerometer as an alternative to a force plate for the step-up-and-over test
	Lindsay Musalem	Biomechanical and electromyographic comparison of isometric trunk flexor endurance tests: Prone "plank" vs. "v-sit"
	Paul Makhoul	Inter- and intra- rater reliability of shoulder range of motion measures when wearing a bomb blast protection suit
	Shawn Beaudette	The dynamic stability of the lumbar spine: A controlled kinematic outcome
	Steven Khuu	The effects of verbal instructions on drop-jump biomechanics implications for athletic performance and injury risk assessment

AN ACCELEROMETER AS AN ALTERNATIVE TO A FORCE PLATE FOR THE STEP-UP-AND-OVER TEST

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Introduction: The step-up-and-over (SUAO) test has been proposed as a measure of knee function in evaluating readiness to return to sport after ACL reconstruction (ACLr). When the repaired leg is responsible for raising and lowering the contralateral limb, the impact force, measured by a force plate, is greater and the total movement time is longer [1]. Unfortunately, force plates with their required equipment, expense and expertise may not be suitable for daily use in the clinic. However, an accelerometer (ACC) may be a simple alternative to the force plate for measuring impact and movement time. Therefore, this study compared measures of impact and movement time using a body-mounted ACC and a force plate during the SUAO test.

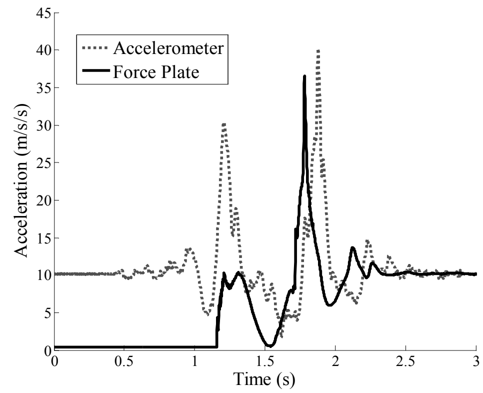

Figure 1: Accelerometer and force plate resultant accelerations during the SUAO test.

Methods: Participants (n=6, thus far) complete 30 trials of the SUAO test: 5 trials for each leg at self-selected slow, medium, and fast speeds. 3D forces were measured using a force plate (BP6001200, AMTI, Watertown, MA, USA) and 3D accelerations were measured using an ACC (Trigno Wireless, Delsys Inc., Natick, MA, USA) mounted on the posterior trunk. Forces were divided by body weight to determine accelerations (also termed the impact index). The maximum resultant accelerations at impact and the movement time from the onset of movement to impact measured by the ACC and the FP were compared using Spearman's correlations.

Results: Figure 1 displays an example of the ACC and FP accelerations during the SUAO. Preliminary results showed very strong relationships between the ACC and FP for impact (ρ=0.96) (Figure 2) and movement time (ρ=0.93).

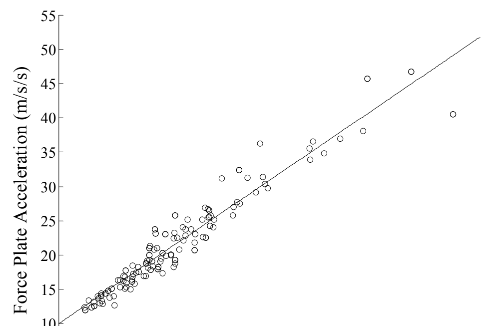

Figure 2: Correlation of the accelerometer and force plate resultant accelerations at the impact of the SUAO test.

Discussion and Conclusions: The results suggest that a tri-axial ACC may be a suitable replacement for a FP when measuring impact and movement time for the SUAO test. An inexpensive accelerometer and appropriate processing software may lead to an effective clinical tool to measure readiness to return to sport.

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BIOMECHANICAL AND ELECTROMYOGRAPHIC COMPARISON OF ISOMETRIC TRUNK FLEXOR ENDURANCE TESTS: PRONE "PLANK" VS. "V-SIT"

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Introduction:
Poor performance on isometric trunk muscle endurance tests has been linked with the development of low-back disorders (LBD) [1]. Holding times during the prone "plank" (PLNK) and/or "v-sit" (VSIT) are commonly used as measures of isometric trunk flexor endurance; however, there is a weak correlation between the holding times on these two tests [2] suggesting that the tests are measure different attributes of muscular performance. The objective of this study was to compare body postures, net low-back flexor moments, and trunk muscle activation between the PLNK and VSIT.

Methods: The study was divided into two parts, both of which required participants to perform the PLNK and VSIT. In Part 1 whole-body kinematic and ground reaction force data were recorded from twenty participants (10 men and 10 women). A static biomechanical analysis was conducted to compute the net L4/L5 joint moment during the PLNK and VSIT. In Part 2, bilateral activation of the rectus abdominis (RA), internal (IO) and external obliques (EO), as well as latissmus dorsi (LAT), lumbar (LES) and thoracic erector spinae (TES) was measured in thirty participants (15 men and 15 women) using electromyography (EMG). Muscle activity was normalized as a percentage of each participant's maximal voluntary isometric contraction. A general linear model was used in both parts, with one within-participant (test) and one between participant (sex) factor.

Results: There was no significant difference between the net trunk flexor moment in the PLNK and VSIT (P = .111). However, its magnitude was approximately 10 N·m (35%) greater in men than in women (P = .003). In Part 2, there were no statistically significant differences in the activation levels of the RA (P = .397), EO (P = .204), IO (P = .226), or LES (P = .116) muscle groups between the PLNK and VSIT. Conversely, activation levels of the TES (P = .0253) and LAT ($P < .001$) were significantly greater in the PLNK than in the VSIT. With the exception of the LAT (P = .008), there were no statistically significant differences in trunk muscle activation levels between men and women in either the PLNK or VSIT ($P > .125$).

Discussion and Conclusions: Results of this study suggest that differences between PLNK and VSIT holding times may be related to between-test differences in shoulder demands as well as lumbar spine and hip postures. Differences in LAT activation also suggest that discrepancies in holding times between the two tests might be due to differing demands unrelated to the trunk flexors.

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INTER- AND INTRA- RATER RELIABILITY OF SHOULDER RANGE OF MOTION MEASURES WHEN WEARING A BOMB BLAST PROTECTION SUIT

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Background: A bomb blast suit is a critical piece of safety equipment used by bomb disposal technicians in Canada. In addition to meeting blast protection standards, a suit must allow users to reach certain gross mobility thresholds as established by the National Institute of Justice (NIJ). To determine whether a suit meets these mobility requirement standards, a single evaluator will measure the gross mobility of a single user (using a manual goniometer), one time in each position. Therefore, the inter- and intra-rater reliability of these measurements is not known and may in fact affect whether or not a suit is certified or not. The purpose of this study was to assess the inter- and intra-rater reliability in measuring the upper extremity gross mobility of participants wearing an EOD 9 Bomb Blast Suit.

Methods: Participants (n = 5) who fit the size requirements of a small EOD 9 Suit (50 - 70 kg, 155 - 175 cm) were included in the study. While wearing the EOD 9 Suit, participants performed a set of three gross body arm movements (flexion, abduction, extension) to maximum. Three raters independently measured participants' maximum arm angles using a manual goniometer. Participants were then given a ten-minute wash-out period where they removed and re-applied the suit. After the washout period they repeated the three gross body movements. Intra-class correlation coefficients were used to estimate intra- and inter-rater reliability.

Results and Discussion: Averaged across raters and repeats, the maximum joint angles obtain in flexion, abduction and extension were 105° (SD = 15), 93° (SD = 12) and 33° (SD = 14), respectively. Correspondingly the standard requirements for these motions are 100°, 90° and 35°. Both inter- and intra-rater reliability were > 0.7; however confidence intervals remain wide, likely due to the limited sample size obtained to date (Table 1). While reliability may be acceptable, the between-participant variation may be of greater concern. When considering how these standards are implemented moving forward, adjustments may need to consider between-participant variability.

References

[1] National Institute of Justice. Public Safety Bomb Suit Standard; NIJ Standard-0117.00, 2012.

Table 1: Intra-class correlation coefficients (ICCs) and confidence intervals (CIs) for inter- and intra- rater reliability. The three gross-body movements are listed, as are the results for the three raters (R1, R2, R3).

Inter-rater			Intra-rater					
			R1		R2		R3	
Measure	**$ICC_{2,1}$**	**CI**	**$ICC_{2,1}$**	**CI**	**$ICC_{2,1}$**	**CI**	**$ICC_{2,1}$**	**CI**
Flexion	.893	.581-.987	.846	.106-.983	.923	.444-.992	.897	.315-.989
Abduction	.956	.803-.995	.783	-.079-.975	.737	-.185-.969	.902	.336-.989
Extension	.822	.392-.978	.855	.143-.984	.931	.490-.993	.975	.783-.997

THE DYNAMIC STABILITY OF THE LUMBAR SPINE: A CONTROLLED KINEMATIC OUTCOME

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Introduction: Many life situations involve the handling of unstable loads, or the lifting of loads on unstable surfaces (e.g. shipping and snow-removal tasks). Destabilized lifting scenarios like these place a challenge on the central nervous system (CNS) to maintain spine stability and avoid injury. An inability for the CNS to compensate for these challenges within the external environment can result in kinematic trajectory variability and the possibility for excessive spine passive tissue strain and subsequent low back pain (LBP) [1]. The goal of this project was to understand mechanisms relating to how the CNS controls movement of the lumbar spine in response to instability in the external lifting environment.

Methods: 15 male participants completed 4 sets of 23 consecutive sagittal lift/lowers (10/min) with a load of 8 kg. Lifting sets included stable control lifts (SSSL), unstable (liquid) load lifts (SSUL), unstable (BOSU ball®) support lifts (USSL) as well as a combination of the unstable load and support (USUL). Lumbar spine angular data were captured and spine angles were processed using a Lyapunov analysis technique within MATLAB to estimate spine local dynamic stability (LDS). Surface electromyography (EMG) data were captured for each lifting scenario, normalized to a maximal value, and entered in conjunction with the spine angles into a biomechanical model to estimate spine rotational stiffness about all three movement axes.

Results: Despite changes in the level of external instability, LDS of the lumbar spine did not differ amongst the 4 lifting conditions ($p = 0.5592$) (Figure 1a). Contrary to the LDS data, the maximum and mean rotational stiffness of the lumbar spine was found to increase with greater external instability, particularly during the unstable support conditions (USSL & USUL) ($p < 0.0001$) (Figure 1b). Concordant with this significant stiffening effect, there was also a significant increase in mean lumbar spine flexion angle during the unstable support lifts ($p = 0.0023$).

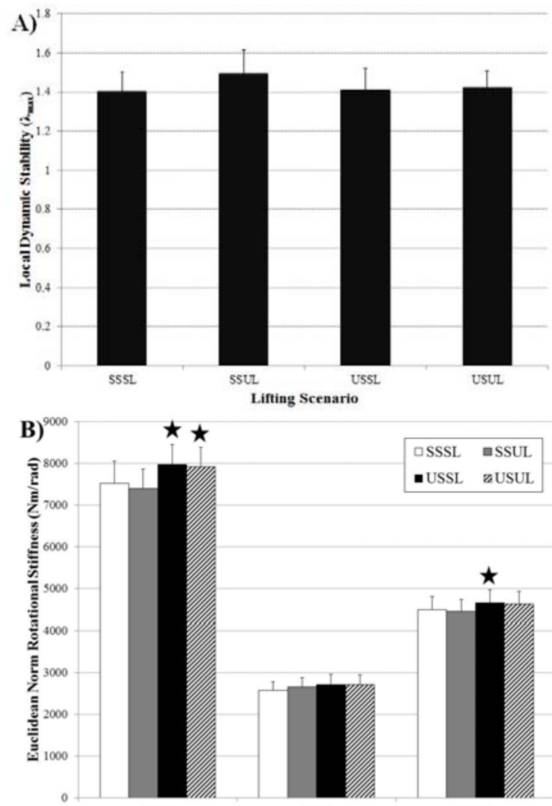

Figure 1: A) Lumbar spine LDS (λmax) for each lifting scenario. B) Maximum, minimum and mean lumbar spine rotational stiffness. Stars show a significant change relative to the SSSL control trial (α = 0.05).

Discussion and Conclusions: Based on these results the LDS of the lumbar spine appears to be conserved and controlled, at least in part, by postural adjustments and active lumbar stiffening in pain free lifters. These findings merit future research designed to understand if the compensatory adjustments observed here in healthy adults are present in populations experiencing LBP.

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[1] Panjabi, M. M., 1992. The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. J. Spinal Disord. 5, 383–389.

THE EFFECTS OF VERBAL INSTRUCTIONS ON DROP-JUMP BIOMECHANICS – IMPLICATIONS FOR ATHLETIC PERFORMANCE AND INJURY RISK ASSESSMENT

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Introduction: Biomechanical quantities acquired during the drop vertical jump (DVJ) are used in the assessment of athletic performance and injury risk [1,2]. Despite the fact that verbal instructions have been demonstrated to influence DVJ mechanics [3], relatively few studies report the specific instructions provided to athletes. The objective was to examine the impact of different verbal instructions on a battery of kinematic and kinetic variables commonly included in DVJ assessments.

Methods: Ten men and 10 women from local varsity and club volleyball, basketball, figure skating, and track and field teams volunteered to participate. After completing a dynamic warm-up, participants performed DVJs after given instructions to: minimize ground contact time (CT); maximize jump height (HT); and synchronously extend the lower extremity joints (EX). The order in which instructions were provided was randomized across participants. Whole-body kinematics were acquired together with ground reaction forces. Visual3D™ was used to produce time histories of body segment and joint angles in addition to vertical ground reaction forces, whole-body power outputs, stiffness, and center-of-mass displacements. From these time histories, peak magnitudes were extracted together with ground contact and flight times. These discrete measures were averaged across 5 trials for each condition, and the means were statistically compared using a one-way ANOVA (general linear model, $\alpha=0.05$).

Results: Verbal instructions were found to influence 53 out of 62 (85%) kinematic and kinetic dependent variables examined. Particularly noteworthy were the findings that athletic performance correlates (e.g., jump height, power output, vertical stiffness, and reactive strength index) and lower extremity injury risk markers (e.g., peak vertical ground reaction force and frontal plane knee angle) were significantly different ($p < 0.05$) between the CT, HT, and EX conditions.

Discussion and Conclusions: Given that nearly all of the biomechanical measures made during the DVJ were influenced by the verbal instructions provided, it is critical that investigators report how study participants were instructed to perform the DVJ. Moreover, practitioners who devise performance enhancement and injury prevention strategies based on DVJ assessments are advised to consider that “coaching” or “cueing” during the task execution could impact conclusions drawn.

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Ontario Biomechanics Conference Podium Presentations
14th-16th March 2014

Podium Sessions G: Sunday 16th March 9:50am – 11:00am

Podium Session	Presenter	Title
G: Muscle Sunday 16th March 9:50am – 11:00am	Alex Waugh	The effect of motor imagery on the co-contraction and recruitment timing of vastus lateralis/vastus medialis obliquus during simple knee flexion-extension exercises
	Dan Mines	Lower leg net muscle activation during kneeling transitions: Comparing effects of mass and location of load
	Diana De Carvalho	Deep low back muscles are not a factor in sitting related pain
	Greig Inglis	Sex-related differences in the rate of torque development in the human tibialis anterior
	Lydia Frost	Lower back and lower limb neuromuscular structure and function in chronic low back pain patients with associated radiculopathy
	Nicole Hills	The relationship between changes in abdominal muscle thickness measured on ultrasound images and muscle activation recorded using fine wire electromyography: A validation study
	Steve May	Effect of wrist posture and rate of force development on finger control and independence

THE EFFECT OF MOTOR IMAGERY ON THE CO-CONTRACTION AND RECRUITMENT TIMING OF VASTUS LATERALIS/VASTUS MEDIALIS OBLIQUUS DURING SIMPLE KNEE FLEXION-EXTENSION EXERCISES

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Introduction: Motor imagery (MI) is a process involving kinesthetic mental simulation that focuses on the feel of performing a given action. The use of MI is correlated to supplementary motor/premotor cortical activation, which subsequently elicits neuromuscular activation in both resting and active muscles [1, 2]. Yet, knowledge of how this technique affects other relevant properties of muscle activation, such as co-contraction and relative onset timing of antagonistic muscle groups, is lacking. The purpose of this study was to reanalyze data from an earlier MI study, to examine the effect of MI engagement on the degree of co-contraction and recruitment timing of the Vastus Lateralis (VL) and Vastus Medialis Obliquus (VMO) muscles.

Methods: 16 female participants (mean age: 21.2 ± 1.2 years) performed three repetitions of two different exercises (traditional squats, and squats with external hip rotation: "pliés"). VL, VMO, and Rectus Femoris recruitment amplitudes were recorded bilaterally using surface EMG. Participants were randomly assigned to an imagery group or a control group. Prior to executing the exercises, all participants were provided verbal instruction on proper execution of the movements. Participants in the imagery group were also read a short imagery script specifically encouraging them to image the function of the VMO while executing the movements. Co-contraction indices (CCI) and latencies of the VMO onsets relative to the VL were calculated for the concentric and eccentric phases of the movement.

Results: While both groups exhibited significantly higher CCIs on the left side than on the right (control: $p < 0.05$; imagery: $p < 0.00001$); the imagery group showed a trend toward higher CCIs than the control group on the left side ($p < 0.1$), but not on the right ($p > 0.70$). Squats also elicited significantly greater co-contraction than pliés ($p < 0.00001$). The VL-VMO activation latency during the eccentric phase was significantly larger for pliés than for squats ($p < 0.001$).

Discussion and Conclusions: The trend toward increased left VL-VMO co-contraction within the imagery group suggests that MI is a salient technique for eliciting muscle activation and contraction. Furthermore, the increases in co-contraction and decreases in VL-VMO phase lags observed during the execution of squats relative to pliés contradict the commonly held notion that the latter emphasizes VMO activation. This may be important in rehabilitation settings that commonly implement the use of pliés to facilitate recovery from injuries where lags in VL-VMO activation are characteristic, such as patellofemoral pain syndrome.

References:

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Lower leg net muscle activation during kneeling transitions: comparing effects of mass and location of load

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Introduction: Previous research has shown strong evidence that occupations involving transitions into and out of kneeling postures or heavy lifting have increased risks of developing knee osteoarthritis. This risk is increased when a combination of both factors is involved in the workplace which is common in many trades[1]. Increased activation of muscles that cross the knee joint has been hypothesized to contribute to the development of knee osteoarthritis (OA)[2]. The aim of this study was to determine how net activation of lower leg muscles is affected by mass and location of load during transitions into and out of kneeling postures.

Methods: Eight healthy participants (4 males, 4 females) were recruited. Participants performed two tasks: (1) Standing to kneeling on heels; (2) Kneeling on heels to standing. This task varied both by mass of the load (2.5 lbs vs. 30 lbs) and by location of load (held symmetrically in front or asymmetrically on the side of the body). Surface EMG was recorded unilaterally (right leg) at 2048Hz for the quadriceps muscle group (vastus medialis, vastus lateralis, and rectus femoris), the hamstrings muscle group (biceps femoris, semitendinosus) and gastrocnemius muscle group. EMG signals were normalized to the maximum amplitude achieved during maximum voluntary contractions. The sum of all MVC normalized muscle groups (“net muscle activation”) was used to provide a surrogate measure of total knee joint compression.

Results: Maximum lower leg net muscle activation was evaluated by performing a three-way ANOVA with factors of task, mass and location. There was a main effect for task ($p<0.001$) and mass ($p<0.012$) but no main effects were found for location of load ($p=0.818$) and all interactions were not significant.

Discussion: Transitioning out of a kneeling posture and carrying a heavier load resulted in higher maximum net muscle activation than getting down into the posture and carrying a lighter load. Since it has been hypothesized that greater net muscle activation results in larger compressive forces on articular surfaces of the knee joint, these results are consistent with earlier studies that suggest occupations that require both frequent transitions into and out of high flexion postures and lifting of heavy loads may potentially be at high risk for knee OA development. Further research should consider a larger sample size, directed co-contraction and bilateral EMG of muscles crossing the knee joint.

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DEEP LOW BACK MUSCLES ARE NOT A FACTOR IN SITTING RELATED PAIN

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Introduction: One pathway that sustained low level muscle contraction can produce irritation and pain is by the production of lactic acid. Previous work examining potential pain pathways in sitting have found very low levels of lumbar muscle activation. However, since the activation of deeper "postural" muscles, such as lumbar multifidus, has been shown to differ from surface measures [1], one must consider the role of these muscles in seated postures. This study explores the indwelling multifidus EMG activity of the low back in response to unsupported sitting.

Methods: Twenty healthy subjects, ten male and ten female were recruited from a student population. Bipolar 44μm gauge, 10cm long fine wire nickel alloy electrodes with 2mm exposed tips bent into hooks (VIASYS Healthcare, Excellence for Life Neurocare Group, Madison, WI, USA), were inserted into the deep multifidus muscle bilaterally at the level of L4/L5 with a 27 gauge hypodermic needle. Surface electrodes (Ag-AgCl, Blue Sensor, Medicotest Inc., Ølstykke, Denmark) were bilaterally affixed with a 2 cm inter-electrode distance and parallel to fibers over the: thoracic erectors, lumbar erectors and lumbar multifidus. EMG signals were band pass filtered from 10-2,000Hz, amplified (AMT-8, Bortec, Calgary, Canada: CMRR=115 db at 60Hz and input impedance = 10 GΩ) and collected at sampling rate of 4,096 Hz with a 16 bit A/D converter (+/- 2.5V range). EMG data were normalized to maximum voluntary contractions of torso extension. Participants then sat on the seat pan of an office chair (backrest removed) and completed a standardized typing task for 40 minutes. Average normalized EMG was calculated for the trial. Rates of perceived low back discomfort were taken at 10 minute intervals on a 10 cm VAS scale with the anchors of "no pain" and "worst pain imaginable". Pain ratings were used to classify subjects into three categories: non pain developer, sub-clinical pain and pain developer. A two-way ANOVA (gender and pain group), was completed to compare the dependent variable of average EMG and a one-way repeated measures ANOVA with depth as the within factor and gender as the between factor was completed to compare indwelling and surface activity (significance taken at $p<0.05$).

Results: Both surface and indwelling EMG activity for the back muscles during unsupported office chair sitting was found to be extremely low (below 5% MVC, Figure 1). Indwelling signals from the lumbar multifidus were the lowest of all muscle groups evaluated in this study (males RMi 0.045549 (SD 0.093409) and LMi 0.151297 (SD 0.34416) and females RMi 0.049985 (SD 0.098622) and LMi 0.692395 (SD 2.343735). There were no significant gender or pain group differences for any of the muscle groups measured and no significant differences between surface and indwelling multifidus activity (R p=0.7635, L p=0.1918).

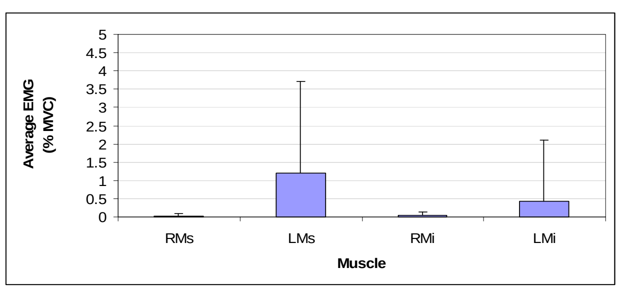

Figure 1: Average normalized EMG for 20 minutes of sitting for the following muscles: bilateral thoracic erectors (RTS, LTS), bilateral lumbar erectors (RLS, LLS), bilateral multifidus at L4/L5 (RMs, LMs) and indwelling bilateral multifidus at L4/L5 (RMi, LMi).

Discussion and Conclusions: Back muscle activity is low during sitting, even when one would expect increased activity to aid in balancing the upper body with no backrest present. Deep lumbar multifidus, a stabilizer of the lumbar spine, is minimally active, no different than surface measures in sitting and not significantly different between genders or pain groups.

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SEX-RELATED DIFFERENCES IN THE RATE OF TORQUE DEVELOPMENT IN THE HUMAN TIBIALIS ANTERIOR

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Introduction: Sex-related differences have been shown to persist in upper limb maximal rate of torque development ($d\tau/dt_{max}$), even after normalization with maximal voluntary contraction (MVC). In contrast, Hannah et al. [1] reported the lower $d\tau/dt_{max}$ exhibited by females during knee extension is accounted for when normalized to MVC. The aim of the present study was to investigate $d\tau/dt_{max}$ during maximal effort isometric actions of the dorsiflexors in both males and females, because this muscle group has great importance with regards to maintaining balance and stability as we age.

Methods: Maximal voluntary isometric contractions and evoked twitch contractions were recorded in thirty-eight participants (20 males and 18 females) on three separate days, separated by at least 48 hours of rest. There were three contractions, each five seconds in duration with a three minute rest interval. Torque and surface electromyographic (sEMG) activity were recorded concurrently.

Results: An analysis of covariance showed that maximal torque differences accounted for all the sex-differences in $d\tau/dt_{max}$ (p=0.34). There were no significant differences between groups with respect to root-mean square amplitude (female: 0.20 ± 0.11mV; male: 0.18 ± 0.11mV) during the MVC or peak-to-peak amplitude (female: 2.16 ± 0.92mV; male: 2.61 ± 1.08mV) of the maximal M-wave produced during the twitch (p=0.58 and p=0.13 respectively). However, there was a significant difference with respect to the rate of increase in tibialis anterior sEMG (female: 8.12 ± 6.26mV × s; male: 5.30 ± 3.01mV × s; p=0.04). Females had longer twitch electromechanical (EMD) times than males (15.69 ± 10.57ms and 9.95 ± 3.46ms respectively; p=0.01), but the voluntary EMD times were the same (32.71 ± 9.94ms and 32.84 ± 12.57ms respectively; p=0.96).

Discussion: It is possible that the greater rate of increase in sEMG for females resulted in comparable EMD times and non-significant differences between groups with respect to $d\tau/dt_{max}$ once differences in MVC have been accounted for. These data suggest that the magnitude of the EMG activation played a less significant role in the sex-related differences compared to the rate of increase in sEMG. Sex-related differences in the $d\tau/dt_{max}$ in the TA may be related to muscle activation strategies at the onset of explosive tasks.

This research was supported by an NSERC.

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LOWER BACK AND LOWER LIMB NEUROMUSCULAR STRUCTURE AND FUNCTION IN CHRONIC LOW BACK PAIN PATIENTS WITH ASSOCIATED RADICULOPATHY

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Introduction: A subset of chronic lower back pain patients suffer from associated radiculopathy (LBP-R), characterized by pain, tingling or numbness down the leg. Previous research investigating LBP-R has focused on measures of the lower back musculature, such as high-resolution ultrasound imaging [1], and muscle activation timing analysis during balance perturbations [2]. However, the pathology associated with LBP-R is not isolated to the lower back, as symptoms follow the sciatic nerve down the leg. Neuromuscular control of the lower limb plays a key role in the response to balance perturbations. Therefore, the purpose of this work is to investigate nerve and muscle structure and function in the lower back and lower limb in a chronic LBP-R population.

Methods: LBP-R patients (n = 10) and matched healthy controls (n = 10) were recruited. High-resolution ultrasound images of the sciatic nerve and associated musculature (erector spinae at L2, biceps femoris, medial gastrocnemius, soleus) were obtained in a rested state and during standardized submaximal contractions. Sciatic nerve cross sectional area (CSA), as well as muscle activation index (thickness contracted / thickness relaxed), were computed. Following this, lower back and leg muscle activation timing was recorded using surface electromyography (EMG) during balance perturbation trials conducted on an AMTI force plate.

Results: Ultrasound image analysis of the sciatic nerve revealed significantly larger nerve CSA in patients relative to controls (p = 0.0015). Additionally, in unilaterally-affected LBP-R patients, the affected side tended towards lower muscle activation index in the erector spinae (4% lower), biceps femoris (4% lower) and soleus (12% lower, p = 0.0331) muscles. There is no convincing evidence of alterations in muscle activation timing during balance perturbations for LBP-R patients. However, force plate centre of pressure (COP) analysis reveals some evidence of reduced COP excursion and velocity in the LBP-R group compared to controls.

Discussion and Conclusions: Nerve root compression in LBP-R results in sciatic nerve inflammation and swelling, shown as an increase in nerve CSA, which supports previous research [3]. Impaired neuromuscular control was demonstrated with trends towards decreased lower back and lower limb muscle activation indices. This finding extends previous research that reported decreased activation index in the lower back musculature [4], by providing preliminary evidence that altered motor control in LBP-R patients is not isolated to the lower back. These findings are not mirrored in the EMG muscle activation data, where there were no between-group differences. Further analysis of balance recovery will bring together this evidence of altered neuromuscular control with functional balance measurements.

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THE RELATIONSHIP BETWEEN CHANGES IN ABDOMINAL MUSCLE THICKNESS MEASURED ON ULTRASOUND IMAGES AND MUSCLE ACTIVATION RECORDED USING FINE WIRE ELECTROMYOGRAPHY: A VALIDATION STUDY

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Introduction: Ultrasound imaging is currently used by physiotherapists as an assessment and biofeedback tool to facilitate contraction of the deep abdominal muscles, which are not readily observable or palpable. Real time imaging provides a visual cue for the patient as they voluntarily control and observe the thickening of the muscle while it contracts [1]. However, there is limited evidence to support that an increase in muscle thickness correlates with a muscle contraction. Electromyography (EMG) is the "gold standard" [2] against which to validate whether muscle thickening seen on ultrasound imaging correlates with EMG activation.

Aim: To investigate changes in the thickness of transverses abdominis (TrA), internal oblique (IO) and external oblique (EO) measured on ultrasound images recorded during muscle activation to determine the relationship between muscle thickening and fine wire EMG activity in both the supine and standing positions.

Methods: Thirteen healthy participants (seven women; six men) between the ages of 18 and 30 performed three maximum voluntary contractions (MVC) and three isometric graded contractions (2.5%MVC-100%MVC) for all three muscles in both supine and standing. TrA was tested during an abdominal in-drawing manoeuvre, IO was tested during an isometric ipsilateral rotation and EO was tested during an isometric contralateral rotation.

Results: In supine a significant linear relationship between the increase in muscle thickness and the increase in EMG activity was found in the TrA, IO and EO muscles during isometric contractions until 100% MVC was reached (slopes: TrA = 0.0296mm/%MVC, IO = 0.0578mm/%MVC, EO = 0.0116mm/%MVC). In standing, a linear relationship between increases in muscle thickness and increase in muscle activation up to 50% MVC in all three muscles was found. After 50% MVC, activity in TrA and EO remained steady [7.21mm ($p=0.000$) in TrA and 8.45mm ($p=0.000$) in EO]. In the IO the thickness continued to increase with increases in EMG activation, but the slope was slightly lower (0.055mm/%MVC vs. 0.058mm/%MVC) than it was during the initial 50% of EMG activation.

Conclusions: Overall the results of this study support the practice of using ultrasound both as a biofeedback device in teaching low level (<50% MVC) activation of the TrA, IO and EO muscles and as a research tool to study muscle activity in an asymptomatic population. However, the slopes are very small suggesting that small differences in muscle activation would be difficult to detect on ultrasound imaging alone.

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EFFECT OF WRIST POSTURE AND RATE OF FORCE DEVELOPMENT ON FINGER CONTROL AND INDEPENDENCE

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Introduction: When asked to move or apply a force with a finger, movements and/or forces also occur in other fingers [1]. This involuntary force production, termed enslaving, is due to a combination of mechanical factors, such as the juncturae tendinei, and neural factors. Since the extrinsic finger muscles are compartmentalized for each finger, a small degree of motor unit synchrony has been observed between adjacent compartments [2]. The extrinsic muscles also cross the wrist, meaning that wrist posture will affect the muscle length and passive muscle force that may alter the amount of enslaving between fingers due to mechanical effects. Additionally, muscle force-length properties and rate of force production may alter neural aspects of enslaving between digits.

Aim: The purpose of this study is to evaluate the effect of wrist posture and rate of force production on finger control and independence.

Figure 1. Experimental set up with adjustable plate to set wrist posture. From Sanei & Keir, 2013

Methods: Fifteen participants will place their fingers in four adjustable padded metal rings, each attached to a force transducer (MLP50, Transducer Techniques, Temecula, CA) (Figure 1). Surface electrodes (Biometrics Ltd., Gwent, UK) will be placed over the four compartments of flexor digitorum superficialis and extensor digitorum. By following a target trace, participants will perform a series of isometric triangular contractions in both flexion and extension directions, which will consist of an ascending phase up to 50% max voluntary contraction, a two second hold, and then a descending phase down to zero force. Participants will perform each triangular contraction at two different rates of force development (2 and 5 seconds). Contractions will be performed for index and ring fingers, at 30° wrist flexion, 0° neutral, and 30° wrist extension, while the elbow is fixed at approximately 120°, and at two different rates of force development for each condition (2 and 5 seconds, for each ramp phase).

Expected Results: It is hypothesized that wrist flexion with isometric finger extension will produce higher enslaving effects than trials in wrist extension, due to increased force in the juncturae tendinei. Since there are no significant structures like the juncturae tendinei between the FDS or FDP tendons, the same increase in enslaving should not be seen in wrist extension with isometric finger flexion. Also, the faster rate of force production should yield greater error from the target trace due to the increased recruitment of larger motor units, which should increase the enslaving effect seen as well. With respect to the target trace, there should be greater error in the ring finger than index, and during the descending phase for both fingers, due to decreased independence and control [3].

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Ontario Biomechanics Conference Podium Presentations
14th-16th March 2014

Podium Sessions H: Sunday 16th March 11:10am – 12:00pm

Podium Session	Presenter	Title
H: Posture, Gait and Balance II Sunday 16th March 11:10am – 12:00pm	Dorelle Hinton	Reaching the limits of cognitive resources: Coping strategies used by children during a multi-task paradigm
	Emily McIntosh	Knee range of motion influences obstacle avoidance strategies in the sagittal plane during gait
	Hannah Moore	Training effects of Tai Chi and compensatory stepping on balance control in older adults
	Liana Tennant	How do work boots affect the location of centre of pressure at the knee during static kneeling?
	Luke Denomme	Individuals with multiple sclerosis with mild balance impairment display similar postural and dynamic balance control characteristics to community-dwelling older adults

REACHING THE LIMITS OF COGNITIVE RESOURCES: COPING STRATEGIES USED BY CHILDREN DURING A MULTI-TASK PARADIGM

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Introduction: Dual motor tasks have been well studied in adults however there is a lack of knowledge concerning strategies used by children during cognitive-motor multitasking paradigms. By age 7, children are capable of adult-like postural strategies with articulated head, trunk and segmental control for most balance tasks [1] but can exhibit '*en bloc'* segmental coordination to simplify complex movements [2]. Interestingly, a common cognitive load assessment tool, the auditory Stroop test, has revealed a 'ceiling effect' in children aged 6 years [3,4] suggesting that by age 7, children can execute motor and cognitive tasks at adult levels when performed separately; however the mechanisms of their integration are largely unknown. The current work increased cognitive load and motor tasks in a stepwise approach, and hypothesized that altered control strategies (e.g. slowing/stopping) would be used as attentional limit was reached in order to maintain balance and correctly answer the Stroop task.

Methods: Healthy children aged 7 years (n=5, 7.22±0.28 years) were instrumented with infrared diodes (IREDs, Optotrak^{TM}, Northern Digital Inc., Waterloo ON, Canada) placed on the head, trunk, pelvis and feet with anatomical points digitized; single IREDs were attached to both elbows and wrists. First, while seated, subjects balanced a ball on a Frisbee with the non-dominant hand and picked up a toy off the ground with the dominant hand (10 trials). To confirm their understanding of the cognitive task, subjects performed the auditory Stroop test while seated (8 trials). In the final task (12 trials) the child balanced the Frisbee and ball while walking, and picked up a toy off the ground. The Stroop test was administered during the child's last step before the toy (6 of 12 trials). Independent variables included posture (seated/walking) and auditory condition (Stroop/No Stroop). From kinematic data, trunk, upper arm (UA) and forearm (FA) absolute angle changes as well as gait parameters were calculated.

Results: Children used a combination of '*en bloc'* and articulated control strategies to maintain Frisbee balance. For example, while seated, absolute trunk and UA changes did not differ (p>0.05; 28.2°±11.3° and 31.9°±10.7° respectively) indicating an '*en bloc'* strategy, however absolute UA and FA changes *were* significantly different (31.9°±10.7° and 13.7°±4.0° respectively; $t_{(1,4)}$=-.603, $p>0.05$) suggesting articulated control of the FA segment. Preliminary findings also indicate children age 7 partition concurrent motor-cognitive tasks; walking speed was significantly slower while answering the Stroop task (0.52±0.51 m/s) compared to their approach to the toy when there was no cognitive task (1.05±0.23 m/s; $t_{(1,3)}$ = 3.637, p<0.05).

Discussion and Conclusions: Our novel paradigm exposes the cognitive and attentional resource limits of children aged 7 years. Strategies to complete individual motor or cognitive tasks are well established in this age group however our findings highlight the use of compensation strategies in order to integrate a complex motor and cognitive task simultaneously.

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KNEE RANGE OF MOTION INFLUENCES OBSTACLE AVOIDANCE STRATEGIES IN THE SAGITTAL PLANE DURING GAIT.

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Introduction: Stepping up onto sidewalks and climbing stairs are common tasks where individuals must adapt their foot placement appropriately in order to be successful. Patla and Rietdyk demonstrated that individuals typically cross barriers with 80° of knee flexion. However, it is unknown how the lower limbs adapt to this task when the knee's range of motion (ROM) is constrained [1]. The purpose of the current study was to examine how a limited ROM of the knee joint would influence obstacle avoidance strategies in the sagittal plane. As the knee was constrained more (less ability to flex) it was expected that the hip joint elevation would play a larger role in the clearance motion over the obstacle. It was hypothesized that the hip height would increase in trials where the knee had less ROM and that minimum toe clearance and foot placement relative to the obstacle would be optimized per condition to allow a safe clearance.

Methods: Eight healthy young adults (4 female, 23.0 ± 1.8 years, 1.7 ± 0.1 m tall, 69.6 ± 15.0 kg) with no history of knee or hip injuries participated. Lower limb kinematic data were collected at 60 Hz with a six camera Optotrak system (Certus, NDI, Waterloo, ON, Canada) using 5 rigid bodies affixed to the pelvis, right thigh and shank, and both feet. Participants had their right knee fitted with a knee brace with manufacturer flexion stops which allowed ROM to be constrained. Four blocks of walking trials were completed for each knee constraint: no brace, 70°, 50°, and 30° (smallest ROM) flexion stop, as measured from full extension. The unbraced block was performed first to establish a baseline, then was followed by three randomized blocks for the brace conditions. These blocks consisted of three randomized conditions (unobstructed walking, 18 cm obstacle, 6 cm obstacle) which each had five trials. Hip height was the vertical location of the greater trochanter at the time of obstacle crossing, while toe clearance and foot placement were defined as the vertical distance from the obstacle to the toe of the lead foot, and the horizontal distance from the obstacle to the trail toe, respectively.

Results: There was no significant difference between any of the trials or conditions for minimum toe clearance above the obstacle or foot placement before the obstacle ($p>0.05$). A main effect of flexion stop on hip height was observed for the high obstacle condition. Hip height was highest for the 30° flexion stop trials, followed by the 50° and 70° of flexion limitation, which were both larger than the non-braced condition.

Discussion and Conclusion: Participants were able to successfully complete the obstacle avoidance task, even with a brace that severely limited ROM. As trials increased in difficulty (i.e. with constrained knee ROM) participants maintained a constant and safe trajectory over the obstacle by increasing their vertical hip height.

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TRAINING EFFECTS OF TAI CHI AND COMPENSATORY STEPPING ON BALANCE CONTROL IN OLDER ADULTS

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Introduction: In Canadian society, there is a growing prevalence of older adults and one of the main problems facing this generation today is the risk of falling[1].Tai Chi (TC) is a martial art that has demonstrated improvements in balance control. It uses a series of fluid movements that engage head, neck and trunk rotation while simultaneously reducing base of support[2]. In addition, it has been demonstrated that training older adults by administering unpredictable perturbations to challenge balance better equips them to react successfully in response to balance perturbations[3].

Aim: To determine the potential balance-specific benefits of a 10-week exercise intervention combining elements of Tai Chi/compensatory stepping among older adults.

Methods: Twenty older adult volunteers aged 65+ will participate in either a TC/compensatory stepping exercise class, or the control strength and walking training class for 10 weeks. The intervention will be delivered 2x/week for 30 minutes. Twenty minutes of each class will be devoted to practicing TC and 10 minutes for compensatory stepping training. Compensatory stepping training will involve the delivery of controlled manual perturbations in either the anterior/posterior or medial/lateral direction. Measures of functional balance will include the Berg Balance Scale and Timed-Up-And-Go (TUG). Pressure insoles and video analysis will be used during quiet standing and gait termination trials to measure balance via variability of, minimum, and maximum values of the centre of pressure (COP) and centre of mass (COM) individually and there interaction.

Expected Results:
It is expected that balance will improve for both groups, but to a greater extent for those who participate in TC. The control group is predicted to demonstrate improved balance control due to increased muscle strength. However, TC improvements are linked to movements that require heightened awareness of foot placement and precise control over the COM throughout weight shifting in addition to muscle strength[4]. Secondly, by incorporating compensatory stepping, it is predicted that training older adults' to respond to unpredictable perturbations will better prepare them to execute successful stepping reactions in real-world challenges to balance[3].

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HOW DO WORK BOOTS AFFECT THE LOCATION OF CENTER OF PRESSURE AT THE KNEE DURING STATIC KNEELING?

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Introduction: Steel toe work boots are required personal protective equipment in the construction industry; however, workers have reported that these boots are inflexible and may restrict some work tasks [1]. Occupational kneeling, as is required by floor layers, is also associated with an increased risk of both tibiofemoral and patellofemoral osteoarthritis [2]. In order to better understand the effects of work boots on injury risk associated with kneeling, center of pressure (COP) was analyzed during kneeling while shod and barefoot. We hypothesized that the mean COP location at the knee would move anteriorly on the force plate (along the longitudinal axis of the tibia) when shod, and would show no differences between conditions in the medial-lateral direction.

Methods: Eight, healthy males with size 10 feet participated (age: 23.9 (±1.5) years; body mass: 79.4 (±13.1) kg; height: 173.0 (±4.4) cm; tibial width: 9.5 (±0.7) cm; tibial length: 34.8 (±1.4) cm). In the shod condition participants wore Caterpillar ® 7" steel toe boots. Kinematics of the sacrum and dominant leg were acquired using a 6 bank 18 camera system (Optotrak Certus and 3020, NDI, Waterloo, ON, CA) sampling at 64 Hz and bony prominences were digitized to generate 3D segment co-ordinate systems. Force data for COP calculations were measured from a force plate under the knee of the dominant leg and sampled at 2048 Hz (OR6-7, AMTI, Watertown, MA, USA). Data were dual-pass low-pass Butterworth filtered (kinematics: 1.5 Hz; COP: 3 Hz). The mean COP location was determined with respect to the tibial tuberosity (normalized to tibial length) and the medial tibial plateau (normalized to tibial width) for the longitudinal and medial/lateral and directions, respectively. COP data were subjected to two dependent sample T-tests ($\alpha=0.05$) with a Bonferroni correction for multiple comparisons.

Results: COP was located anterior to the tibial tuberosity, with no difference between conditions (shod 11% (±2.3%) tibial length, barefoot: (10%) (±3.8%) tibial length) ($p=0.42$). COP was located more medially in the shod condition (31% (±6.4%) tibial width) compared to the barefoot condition (36% (±7.2%) tibial width) ($p=0.009$).

Discussion and Conclusions: COP was always located over the medial compartment of the knee, which may correspond with the increased incidence of medial tibiofemoral osteoarthritis in occupational kneelers [1]. Application of the ground reaction force above tibial tuberosity suggests repetitive loading of patella or patellar tendon, which may also contribute to injury risk. Small sample size is a limitation and a larger study sample will be recruited in future work.

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INDIVIDUALS WITH MULTIPLE SCLEROSIS WITH MILD BALANCE IMPAIRMENT DISPLAY SIMILAR POSTURAL AND DYNAMIC BALANCE CONTROL CHARACTERISTICS TO COMMUNITY-DWELLING OLDER ADULTS

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Introduction. Individuals with Multiple sclerosis (IwMS) are thought to possess somatosensory-related deficits resulting in impaired static and dynamic balance control[1]. Evidence suggests that balance differences may exist between IwMS with mild balance disability and healthy controls during standing and walking balance tests in a laboratory setting[2]. The purpose of this study was to determine whether differences in static and dynamic balance control exist between IwMS and older adults (OA); a novel comparison population to IwMS which experiences balance impairments as a result of suspected somatosensory loss due to natural aging.

Methods. 12 IwMS ($\mu = 44 \pm 9.4$ years) and 12 OA ($\mu = 68 \pm 4.5$ years) stood on a force platform with feet together and arms by their sides for 45s with either eyes open or closed to assess static control of balance (COP_{RMS} displacement, COP_{RMS} velocity, and Standing Index). Participants also performed a 9m walking task (6.2m straight + 2.5m change in direction) to assess differences in gait characteristics (i.e., velocity, step length/width, double support time, trunk roll) and temporal/spatial dynamic stability margin (medial-lateral (ML) distance between COM and BOS) during single support. Gait measurements were analyzed using an NDI Optotrak Certus system (NDI Inc., Waterloo, ON), while static measurements used a Burtec force platform (Burtec Inc., Columbus, OH).

Results. *Standing Task:* Results revealed that OA displayed a much smaller COP_{RMS} displacement than IwMS ($p<0.05$). However, there was no main effect of group for anterior-posterior (AP) or ML COP_{RMS} velocity and Standing Index measures ($p>0.05$). A main effect of visual condition revealed that both groups displayed reduced postural control in both the AP and ML direction with eyes closed than with eyes open (i.e., faster COP_{RMS} velocity and higher Standing Index) ($p<0.01$). *Steering Task:* Gait characteristics and lateral dynamic stability margin (during single support phase of gait) were calculated and separated into three distinct walking task phases (approach (straight walking), anticipatory postural adjustment (2 steps prior to turn), and turning). Results revealed no differences between groups during each walking task phase for all gait characteristics as well as lateral dynamic stability margin.

Discussion and Conclusions: Findings from this study demonstrate that individuals with less sensitive (OA) and less intact (IwMS) somatosensory systems performed similarly on both tasks despite differences in the nature of their somatosensory impairment. Both groups used various balance control strategies to help regulate their standing and walking balance (e.g., walked extremely slow during the walking task and shifted the pressure under their feet faster to regain control of their swaying trunk during eyes closed standing situations). These findings present novel insights which highlight that balance impairment arising from suspected contribution of somatosensory impairments in aging is similar to that experienced by individuals with isolated somatosensory impairments observed in IwMS.

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