Research Project Title: The complex relationship between resting heart rate variability and distress tolerance

Student Presenter: Sogand Abbasi

Faculty Mentor: DeWayne Williams

Faculty Mentor Department: Psychology

Research Abstract: Distress tolerance is defined as the capacity to experience and withstand a negative physiological state. Brain areas related to emotion regulation processes have also been associated with distress. Importantly, distress tolerance is thought to be related to emotion regulation abilities. Resting heart rate variability (rHRV), is defined as measurement between changes in time between successive heart beats and is best used to measure a tolerance of stress. rHRV is regulated via similar brain areas associated with distress. Given this information, rHRV and stress tolerance should be related to one another, however researchers have not directly tested the relationship between rHRV and self-reported distress tolerance. In this preliminary investigation, the relationship between rHRV and distress tolerance examined in 40 undergraduate participants. There were 21 female participants and 19 male participants who completed a 5-minute baseline resting period while rHRV was recorded. Following this period, participants were to answer a set of questionnaires including the Distress Tolerance Scale (DTS). The participants answered on a 1 to 5 scale, which represented strongly agreeing to strongly disagreeing. The DTS included four subscales including distress tolerance, absorption, appraisal, and regulation. Total distress tolerance was calculated using an average of four subscales. A higher score represented a higher distress tolerance. In the study, it was found that rHRV was not related to total distress tolerance ($r = .002, p=.713$) or any associated subscale (each $p > .425$). However, when the sample was split between sex, men showed a positive association (higher rHRV associated with higher distress tolerance) as we would predict ($r =.568, p = .064$). In contrast, women showed a negative association ($r =-.424, p =.033$). The difference between correlation coefficients between men and women were significantly different ($p =.008$). Overall, this data suggests that the interaction between sex and rHRV can be used to predict distress tolerance. Implications regarding the impact of sex on the relationship between rHRV and distress tolerance will be discussed.
Research Project Title: The relationship between the gross motor functional measure and the Bayley Scales of Infant Development in infants with Cerebral Palsy

Student Presenter: Madison Allen

Faculty Mentor: Jill Heathcock

Faculty Mentor Department: Health and Rehabilitation Sciences

Research Abstract: Background: Cerebral palsy (CP) is the most common motor disorder in childhood. This disorder results in abnormal posture, muscle tone, and functional movement greatly influencing child development. The Gross Motor Functional Measure 88 (GMFM-88) and the Bayley Scales of Infant and Toddler Development (Bayley-III) are two tools used to measure motor function in infants with developmental disabilities including CP. The purpose of this project is to describe the relationship between the GMFM-88 and the motor scale of the Bayley-III as measures of gross motor function in infants with moderate to severe CP.

Methods: N = 25 children with CP aged 6-24 months participated in this study (14.8 +/- 5.27). Infants were part of larger study on dosing of rehabilitation. Testing was done in a single session for ~ 45 – 60 minutes to administer both tests. Best fit regression model was completed using IBM SPSS 23.

Results: A quadratic regression model showed best fit, indicating a significant, large, and positive relationship between the GMFM-88 and the motor scale of the Bayley-III (p = &lt; 0.001, r= 0.949, F =99.5). The quadratic regression line began to plateau at GMFM-88 gross motor score of 45 and Bayley-III score of 37.

Conclusions: Infants with CP scored ~ 10 months delayed. Their scores had high positive relationships on both tests, which may suggest they are measuring the same thing (gross motor skills). Children with moderate to severe cerebral palsy may experience a plateau in gross motor skills shown in this regression analysis. It is imperative to design strategic clinical interventions to further develop gross motor skills in this population. Further study tracking if the correlation remains strong as the participants work to improve their gross motor function through rehabilitation is underway.
Research Project Title: Two-dimensional motion analysis of lower extremity frontal plane movement following neuromuscular training after anterior cruciate ligament reconstruction

Student Presenter: Michael Collins

Faculty Mentor: Stephanie Di Stasi

Faculty Mentor Department: Sports Medicine Research

Research Abstract: Collins M, Pottkotter K, Di Stasi S

Athletes who undergo anterior cruciate ligament reconstruction (ACLR) have a 20-30% chance of sustaining a second ACL injury on either limb. Poor biomechanics of the lower extremity increases risk for a second ACL injury. Neuromuscular Training (NMT) programs improve lower extremity biomechanics and reduce the incidence of first time ACL injury, but its effect on the biomechanics of athletes following ACLR has not been studied. The purpose of this study was to evaluate the effects of NMT on frontal plane hip and knee motion during a single leg hop for distance (SLH) in athletes post-ACLR. We hypothesized that athletes would demonstrate a reduction in peak frontal plane hip and knee motion on both limbs after NMT. Twenty-two athletes who underwent ACLR (age: 20.9 ± 6.7 years; 12 female/10 male; BMI: 25.6 ± 4.0; post-ACLR: 7.2 months) completed a 6-week NMT program aimed at optimizing movement biomechanics. Before and after NMT, athletes were recorded with a GoPro (GoPro Hero4) as they performed two trials of a SLH on each limb. The trial with the longest hop distance was chosen for data analysis. Kinovea (Kinovea 0.8.15), a two-dimensional (2D) video analysis software, was used to quantify the peak frontal plane hip and knee motion during the SLH landing. The peak angle measurements were recorded; knee abduction and hip adduction were expressed as positive values. A repeated measures ANOVA was performed to determine changes in peak hip and knee angles over time. There was no statistically significant interaction for peak hip or knee motion in the frontal plane (p = 0.227). There were also no main effects of time or limb for either the hip (p = 0.930; p = 0.954) or knee (p = 0.345; p = 0.108), respectively. On average, athletes demonstrated less than 4° of peak frontal plane motion at the hip and knee, regardless of limb or time. While the data did not support our hypothesis, it revealed large variability in movement patterns which may have masked positive effects of NMT for some individuals. Future research to determine changes in biomechanics during a SLH by comparing 2-D movement analysis to three-dimensional movement analysis is warranted.
Research Project Title: Simple metrics of gait changes before and after total knee arthroplasty

Student Presenter: Brooke Delventhal

Faculty Mentor: Robert Siston

Faculty Mentor Department: Mechanical and Aerospace Engineering

Research Abstract: The way that people walk can change as a function of age and the progression of disease. Previous research has shown that older people tend to walk with a slower speed, exert more control at the hip joint, and exhibit reduced control at the knee and ankle joints. The onset of knee osteoarthritis (OA) causes muscle weakness and knee instability, and results in a decreased knee range of motion in OA patients. Advanced cases of OA require a total knee arthroplasty (TKA) in attempt to restore original joint anatomy, but suboptimal outcomes are very common, and leave patients with remaining knee instability and walking abnormalities. Current literature includes many variables, potentially causing difficult comparisons between populations. The purpose of this study is to apply a single, simplified metric to identify the differences of gait between patients with OA, before and after TKA. Using existing motion capture data from each of these populations, the footpath trajectory was plotted with respect to a fixed reference point of the hip joint, forming a shape that resembles an ellipse. These plots were analyzed for each population using their respective length, area, density, and angles. These characteristics were correlated to patient-reported outcome surveys (KOOS). Preliminary comparisons between OA and 6-month post-TKA data have revealed no relationship between footpath trajectory and clinical outcomes before or after surgery. However, those patients who improved after surgery walked with a footpath that was longer in length and more parallel to the ground than before surgery. Future work will investigate these patients 24-months post-TKA and make additional comparisons to cohorts of young and old healthy adults. Understanding how these simple measurements can characterize the differences of gait between patient populations can give healthcare professionals a tool to concentrate rehabilitation techniques based on current patient condition.
Research Project Title: Knee loading asymmetries during a double-leg squat exist at 3 months but not 6 months after pediatric anterior cruciate ligament reconstruction

Student Presenter: Gina Gugliotta

Faculty Mentor: Laura Schmitt

Faculty Mentor Department: School of Health and Rehabilitation Sciences-Physical Therapy

Research Abstract: The incidence of anterior cruciate ligament reconstruction (ACLR) in children has risen substantially in recent years. While outcomes following ACLR have been extensively studied in the skeletally mature population, little is known regarding outcomes in a skeletally immature population. The purpose of this study was to examine knee joint kinetic and kinematic variables during a double-leg squat in children at 3 months and 6 months after pediatric ACLR (pACLR), as movement asymmetries during dynamic activities have been shown to increase risk of poor outcomes in skeletally mature individuals after ACLR. Eight subjects (100% male, 11.2+/-1.77 years) were examined at 3 months and seven subjects (100% male, 11.8+/-1.90 years) were examined at 6 months after primary, unilateral epiphyseal-sparing ACLR with an iliotibial band autograft. Biomechanical data was collected during a double-leg squat utilizing a 12 camera 3-dimensional motion analysis system synchronized with 2 imbedded force plates. Variables of interest include peak vertical ground reaction force (vGRF), peak knee flexion angle (PKFA), and peak internal knee extension moment (PIKEM). Differences between limbs were compared utilizing paired t tests (p&lt;0.05). At 3 months following pACLR, subjects demonstrated significant differences between limbs in vGRF (involved: 0.54+/-0.05 % body weight, uninvolved: 0.67+/-0.05, p=0.002), but not PKFA (p=0.974). However, at 6 months following pACLR, no significant differences between limbs were demonstrated for any of the variables of interest (all p&gt;0.05). These results suggest that children demonstrate asymmetric knee loading patterns and may favor their uninvolved limb during dynamic activities at 3 months following pACLR, but that sagittal plane knee mechanics appear to have normalized by 6 months after reconstruction. This trend may demonstrate a reduced risk of reinjury during return-to-sport performance, typically evaluated at 6 months post-pACLR. Further research within a larger, more heterogeneous population is warranted to further examine early movement asymmetries in individuals following pACLR. Early identification of these asymmetries may help guide rehabilitation specialists and lead to early identification of individuals who may be at risk for poor outcome, allowing for earlier targeted rehabilitative strategies to reduce this risk.
Research Project Title: The relationship between resting heart rate variability and facets of rumination: an update

Student Presenter: Catalin Dragomirescu

Faculty Mentor: Julian Thayer

Faculty Mentor Department: psychology

Research Abstract: Resting vagally mediated heart rate variability (vmHRV) is an indicator of self-regulation abilities, stress vulnerability, and overall health. Perseverative cognition is the constant thinking about negative events, and is considered a primary mechanism linking stress vulnerability to poor health and disease. Rumination, a type of perseverative cognition, is thought to subsume three unique facets of rumination: depressive, brooding, and reflective. Our group previously demonstrated, in a sample of 203 participants, that resting vmHRV was associated with maladaptive (e.g., depressive) but not adaptive (e.g., reflective) facets of rumination (Williams et al., 2017). Specifically, people with lower resting vmHRV were more likely to exhibit perseverative cognition, perhaps because they are more vulnerable to stress. In the current study, we present an update of this relationship using a larger dataset of 583 participants (313 female, mean age = 19.40). A baseline period of five-minutes was used to assess the root mean square of successive differences (log transformed) in accordance with Task Force (1996) guidelines, and was used as the measure of resting vmHRV. Zero-order correlation results showed a significant negative association between resting vmHRV and rumination-total score (r= -.141, p= .030), depressive rumination (r= -.170, p< .001), and brooding rumination (r= -.110, p= .023), but not for reflective rumination (r= -.051 p= .288). However, when examining the relationship between resting vmHRV and each facet of rumination while controlling for the other two, only depressive rumination (r partial= -.151, p= .002) showed a significant negative correlation whereas reflective (r partial= .075, p= .121) and brooding (r partial= .013, p= .783) rumination did not. This data replicates results from our previous report, having showed a significant negative correlation with resting vmHRV. This data further suggests that depressive rumination is a primary facet of rumination linked with resting vmHRV. Overall, our data propose that theories and research surrounding perseverative cognition should consider various facets of rumination, as some may be more related to physiological processes than others.
Research Project Title: The influence of defect location on sagittal plane gait mechanics in individuals with knee articular cartilage defect.

Student Presenter: Carl Higbea

Faculty Mentor: Laura Schmitt

Faculty Mentor Department: Sports Medicine

Research Abstract: The presence of articular cartilage defect (ACD) in the knee has been shown to alter joint loading patterns. In regards to defect location, previous research has shown that individuals with ACD in the patellofemoral (PF) compartment of the knee have a faster gait speed than those with ACD in the tibiofemoral (TF) compartment. The purpose of this study was to determine if sagittal plane gait mechanics in individuals with knee ACD differed based on defect location. This study involved 33 individuals, between 18-55 years old, with unilateral, full-thickness knee ACD in either the PF compartment (n=17, 8 female, 7 male; mean age 30.4 years old) or the TF compartment (n=16, 10 female, 6 male; mean age 31.7 years old). Three-dimensional motion analysis data were collected on the involved limb of subjects in both groups during five gait trials at a self-selected walking speed. Variables of interest included vertical ground reaction forces and sagittal plane knee kinematic and kinetic variables during stance phase of the gait cycle. Stance phase of the gait cycle was subdivided into loading, early, middle, and late phases. Results showed that ground reaction forces during the midstance portion of stance phase were lower in the PF group (0.59 N +/- 0.22) compared to the TF group (0.75 N +/- 0.21) (p=0.05). There was a trend for lower internal knee extension moments in the TF group (0.29 Nm/Nm +/- 0.01) compared to the PF group (0.27 Nm/Nm +/- 0.01) (p=0.096). There were no differences demonstrated in knee flexion angle during weight acceptance phases of stance (loading and early phases) (PF=16.4 degrees +/- 4.3 and TF=13.7 degrees +/- 5.9; p=0.14) or single limb support phase of stance (middle phase) (PF=3.3 degrees +/- 3.4 and TF=4.0 degrees +/- 4.4; p=0.57). In conclusion, there were no appreciable differences in sagittal plane knee kinematic or kinetic variables during stance phase of gait between individuals with PF ACD and TF ACD. Further research should investigate the influence of defect location on other variables of gait mechanics among individuals with knee ACD, including those in the frontal plane.
Research Project Title: The relation of ankle dorsiflexion range of motion during takeoff and landing to anterior single leg hop for distance

Student Presenter: Tommy Hirsch

Faculty Mentor: James Onate

Faculty Mentor Department: Sports Medicine

Research Abstract: Background: Anterior single leg hop for distance (SLHOP) tasks are used clinically to gauge rehabilitation progress in patients following lower extremity (LE) injury. Biomechanical determinants of SLHOP performance may direct clinicians in developing effective rehabilitation protocols. One potential modifiable determinant of SLHOP performance is ankle dorsiflexion (DF) range of motion (ROM). Therefore, the purpose of this study was to determine if ankle DF ROM during a SLHOP task was related to SLHOP performance.

Methods: Seven recreationally-active adults participated in this study (Leg length=91.5±4.5cm., Mass=76.7±8.6kg). Subjects were tested using a three-dimensional motion capture system (Vicon Motion Systems Ltd., Oxford, UK). Subjects performed three SLHOP with instructions to jump as far as possible in the anterior direction on one leg, land on the same leg, and maintain a controlled stance position for at least 2 seconds. Hop distance was recorded in centimeters and converted to a percentage of the participant’s leg length. Maximum ankle DF ROM, minimum ankle DF ROM, and ankle DF ROM excursion were recorded in degrees. Maximum ankle DF ROM was determined at the moment with the least degrees of separation between the shank and foot; Minimum ankle DF ROM was observed at the moment with the most degrees of separation between the shank and foot. Excursion was calculated as the difference between the maximum and minimum ankle DF angle observed during the hop. These metrics were recorded during both takeoff and landing.

Results: Participants hopped an average of 214.2±16.1% of their leg length. Anterior SLHOP distance was significantly related to maximum ankle DF ROM during both landing (r=0.53, p=0.002) and takeoff (r=0.46, p=0.005). No significant relationships were found between SLHOP and ankle DF ROM excursion during landing (r=0.11, p=0.55), takeoff (r=0.15, p=0.37) or minimum ankle DF ROM during landing (r=0.14, p=0.45) or takeoff (r=0.27, p=0.11).

Discussion: DF ROM is an important component of SLHOP performance. Clinicians using SLHOP in return to play considerations may want to focus on active and passive DF ROM in rehabilitation programs post LE injury. Unilateral closed chain exercises with a focus on maximum DF ROM may lead to improved SLHOP performance.
Research Project Title: Cytotoxicity of a novel magnesium alloy for resorbable bone fixation devices

Student Presenter: Tim McManus

Faculty Mentor: David Dean

Faculty Mentor Department: Plastic Surgery

Research Abstract: Introduction

Permanent metal skeletal instrumentation, including fixation and joint replacement devices, have been shown to fail due to: stress shielding leading to a resorption of surrounding bone, stress concentrations causing device failure by fatigue, or sensitizing surrounding tissue with corrosion (resorption) byproducts or wear detritus.1 We are investigating the use of resorbable magnesium as an alternative to the current standard of care material, Ti6Al4V. A resorbable implant would eliminate the need for a second surgery and gradually transfer all mechanical loading to the bone. Magnesium, the fourth most abundant cation found in the body,4,5 has been chosen both because of its likely biocompatibility and its similar mechanical properties to bone which we can modulate in the Mg alloy that we are studying.

Methods

We report here on an in-vitro investigation of the potential cytotoxicity of pure Mg versus our untreated (i.e., as-cast) Mg1.2Zn0.5Ca0.5Mn alloy. The effects of metal extract media on L929 murine fibroblast viability after 0, 24, and 72 hours was measured using the PrestoBlue Metabolic Assay. Metal extract media was formed by soaking alloy coupons in complete media for 72 hours, which was then collected and diluted with complete media into four groups (1x, 2.5x, 6x and 10x)2. Two â€œpre-treatedâ€ Mg alloy groups that were soaked in fetal bovine serum (FBS) for one week and four weeks, respectively, were also included to investigate long term effluent cytotoxicity.

Results/Conclusion

The experiment resulted in, as expected, no viability for pure Mg samples and statistically significant better (reduced) cytotoxicity for our Mg alloy. At 6x dilution or higher the effluent of our alloy was deemed non-cytotoxic. Our next study will look at longer periods of FBS soaking, strengthening heat treatment, micro arc oxidation coating, and sol gel ceramic coating treatments to reduce cytotoxicity.3,4
Research Project Title: Poor quality of movement, but not weakness, are evident in persons after surgery for femoroacetabular impingement syndrome

Student Presenter: Breanne Huffman

Faculty Mentor: Stephanie Di Stasi

Faculty Mentor Department: Health and Rehabilitation Sciences

Research Abstract: Introduction: Femoroacetabular impingement syndrome (FAIS) is a painful clinical condition of the hip often associated with weakness and abnormal movement. Surgery does not resolve poor movement patterns, which may explain continued functional limitations. The purpose of this study was to compare (1) prevalence of poor quality of movement and (2) hip and thigh strength of persons after surgery for FAIS to healthy controls (HCs). We hypothesized poor quality of movement during a forward step-down (FSD) and hip and thigh weakness would be more prevalent in individuals post-arthroscopy for FAIS when compared to HCs. Methods: 25 participants 2.5 years post-surgery for FAIS (2.5±1.0yrs post-arthroscopy, 68% female, age:36.4±7yrs, BMI:25.1±2.0kg/m2) were compared to 15 HCs (60% female, age:31.4±7yrs, BMI:25.0±2.6kg/m2). Three physical therapists rated quality of movement based on predetermined criteria; trunk, pelvis, and knee position were dichotomized as good or poor during the FSD. Hip abduction and extension strength were measured with a handheld dynamometer during maximum voluntary isometric contractions, then normalized by participant height and mass. Normalized isokinetic knee extension was measured using an isokinetic dynamometer. Chi-square tests were performed to compare the prevalence of poor quality of movement at the trunk, pelvis, and knee between groups, regardless of limb (P<0.05). Independent sample t-tests were performed to compare strength of the FAIS group (surgical limb) to the HC group (dominant limb; P<0.05). Results: There was a higher prevalence of poor trunk (FAIS:79.5%; HC:60%) and knee (FAIS:79.5%; HC:53.4%) positioning in the FAIS group compared to HCs. Prevalence of poor quality of movement for pelvis positioning was not significantly different between groups (FAIS:97.9%, HC:97.4%; P=0.92). Hip abduction (FAIS:0.30±0.20N/m*kg, HC:0.40±0.16N/m*kg, P=0.13), hip extension (FAIS:0.36±0.22N/m*kg, HC:0.40±0.17N/m*kg, P=0.57), and knee extension strength (FAIS:142.73±45.27Nm, HC:136.17±49.05Nm, P=0.69) did not differ between groups. Conclusions: Poor pelvic positioning was highly prevalent in both groups. Poor trunk and knee positioning were more prevalent in the FAIS group. The presence of poor movement despite normal strength indicates that a strength-only rehabilitation approach may be ineffective in resolving movement impairments. The FSD task requires neuromuscular control across multiple repetitions, future work should consider other clinical factors that may explain deficits in quality of movement.
Research Abstract: Introduction

The single leg hop test is performed as a functional movement assessment of lower extremity power in athletes. Understanding how force production influences hop distance may help develop targeted training programs to increase lower extremity performance. The purpose of this study was to determine the association between dynamic force production and hop distance. It was hypothesized that athletes that produce greater force, and at a higher rate, would hop farther. Eighteen NCAA Division I women’s soccer players participated (height=1.67 ± 0.07 m, mass=62.8 ± 7.1 kg).

Methods

Horizontal and vertical ground reaction forces were recorded at 1200 Hz using a tri-axial force plate (Bertec Co. Worthington, OH) while participants performed three single leg hops forward for distance, with distance recorded in cm with a cloth tape measure. Rate of force development is calculated as the change in force over time.

Results

A linear regression analysis with a best subset selection method was performed to assess relationships between peak force and peak rate of force development in horizontal and vertical directions, independent of height and mass. A combination of peak horizontal force ($\beta=0.316, 95\% \text{CI}= 0.187, 0.445, p<0.001$), peak horizontal rate of force development ($\beta=-0.013, 95\% \text{CI}= -0.027, 0.001, p=0.063$), mass ($\beta=-1.96, 95\% \text{CI}= -3.22, -0.70, p=0.005$) and height ($\beta=1.53, 95\% \text{CI}= 0.20,2.87, p=0.028$) were all significantly associated with hop distance. The linear regression model explains 76.3% of the variance of single leg hop distance among women’s collegiate soccer players.

Conclusions

The model suggests that athletes that are taller jump farther, and those with more mass are not able to jump as far. Additionally, athletes who jump farther generate more force horizontally, and are able to sustain horizontal force production over the concentric phase of the jump. Training using exercises that emphasize sustained horizontal force production, such as sled pulls and incline training, along with strength and plyometric training, may help to improve lower extremity performance. Further research is needed to understand how lower extremity joints, such as the hip and knee, may contribute to horizontal force production.
Research Project Title: Parametric analysis to optimize calculated head segment mass from computed tomography scans

Student Presenter: Laura Jurewicz

Faculty Mentor: Yun Seok Kang

Faculty Mentor Department: Health and Rehabilitation Sciences

Research Abstract: Human body segment properties, such as mass, are critical when studying the biomechanics of the body. Previous studies have investigated methods for obtaining mass of physically segmented heads of post mortem human surrogates (PMHS) using scales and commercial software to analyze CT scans of the heads, resulting in some deviation. It is important to find an accurate minimally invasive technique so precise body segment mass could be found on live subjects.

The objective of this study was to minimize the error of the segmented head mass computed from a custom MATLAB code when compared with the known physical mass by varying bone and tissue densities and Hounsfield unit (HU) thresholds obtained from previous literature.

This study compared physical mass data of the heads of 25 PMHS to CT scans of those same heads to find the most precise tissue densities and HU to use when computing segment mass. The subjects consisted of 10 males and 15 females that had been segmented and weighed for a previous study. A custom MATLAB code was created to convert the pixel values in each CT image to representative masses, which were then summed to find total head mass.

Trials were tested that used different combinations of possible HU and density values in the MATLAB code. The HU values of -200 to 400 for soft tissue and 401 to 1800 for bone, and 538 to 707 for soft tissue and 708 to 3500 for bone were tested in different combinations with density values of 1.00 g/cm³ for soft tissue and 1.92 g/cm³ for bone, and 1.04 g/cm³ for soft tissue and 1.21 g/cm³ for bone. The lowest percent error of 4.29% ± 5.79% resulted from using soft tissue density of 1.00 g/cm³ and bone density of 1.92 g/cm³ with soft tissue HU between -200 and 400, and bone HU between 401 and 1800. Future work could optimize density or HU values to even further decrease the percent error.

Finding an accurate and non-invasive technique to measure segment body mass would provide more data from live subjects in dynamic analysis of biomechanics studies.
Research Project Title: Assessing methodology and sexual dimorphism for tibia cortical thickness (Ct.Th)

Student Presenter: Kathryn Lane

Faculty Mentor: Randee Hunter

Faculty Mentor Department: Health and Rehabilitation Sciences

Research Abstract: Computed tomography (CT) is a prevalent clinical instrument providing images that can be used to assess bone quality. Quantifying bone quality across various skeletal elements is important in understanding fracture risk. Cortical thickness (Ct.Th) has been established as an important predictor of bone strength across the skeleton in both sexes; however, methods used to quantify the parameter need to be investigated. Data are lacking in the ability of commercially available SkyScan CTAn (Bruker) software to quantify Ct.Th from CT scans in males and females who experience differential processes of bone loss during aging. Therefore, the purpose of this study is twofold; first, to validate the automated process used by SkyScan to measure Ct.Th against manual measurements conducted in ImageJ (NIH); and second, to quantify the variation in Ct.Th by sex as it relates to the accuracy of SkyScan Ct.Th analyses. Forty ex-vivo tibiae were obtained from 20 post-mortem human subjects (PMHS) ranging from 45 to 81 years (mean 59.6 ± 11.0). Ten male and ten female subjects were age-matched to within 5 years. Tibiae were scanned on a Philips Ingenuity 64-slice CT. Acquisition parameters were consistent, resulting in an in-plane resolution of 0.335mm. Images were imported into SkyScan for analysis and segmented into 38%, 50%, and 66% volumes of interest (VOI) relative to the distal articular surface. OsiriX MD (v.8.0.1) was used to similarly segment tibiae for ImageJ analysis. Manual measurements of Ct.Th were performed at 8 equidistant locations across each tibial cross-section. SkyScan and ImageJ Ct.Th values did not demonstrate significant differences between methods along the length of the tibia; however, an ANOVA revealed that SkyScan Ct.Th measurements significantly differed between VOIs (p<0.01). At each of these segments, an independent samples t-test confirmed males have larger average Ct.Th than females (p<0.001). Thus, automated Ct.Th quantification by SkyScan produces comparable results to manual methods performed using ImageJ for both sexes despite significant variation in amount of bone present relative to sex as well as along the length of the diaphysis of the tibia. These findings could greatly improve fracture assessment given sex differences in Ct.Th.
Research Project Title: Relationship between throwing kinematics and elbow varus torque in adolescent baseball

Student Presenter: Michael Lantz

Faculty Mentor: James Onate

Faculty Mentor Department: School of Health and Rehabilitation Sciences

Research Abstract: High elbow varus torque is suggested to be a risk factor for elbow injuries in baseball players. Identifying modifiable pitching kinematics related to elbow varus torque may help inform prevention strategies to reduce risk of injury. Therefore, the purpose of this study was to analyze if upper extremity pitching kinematics are related to elbow varus torque in adolescent baseball players.

Twenty-six participants from five high school baseball teams volunteered for this study. Participants wore a compression sleeve containing a lightweight, 6-axis inertial measurement unit (motusBASEBALL, Motus Global, Rockville Centre, NY) during games and practices. The sleeve provides pitching kinematics for arm slot, arm speed, shoulder external rotation, and elbow stress for each throw. Arm slot was defined as the angle between the forearm and the ground during ball release. Arm speed was maximal rotational velocity (degrees/sec) of the forearm during the throw. Shoulder external rotation was measured relative to the ground. Elbow stress was an estimate of the peak torque acting to resist varus motion at the elbow. A mixed effects linear regression with standardized coefficients was used to assess the relationship between variables. Statistical significance was determined a priori at p < 0.05.

Subjects performed a combined 25,892 throws. Arm slot, arm speed, and shoulder rotation were all significantly related to elbow torque. For every standard deviation change in arm slot, a 1.23 Nm change in elbow varus torque occurred (95%CI=1.06, 1.41; p<0.001). For every standard deviation change in arm speed, a 9.41 Nm change in elbow varus torque occurred (95%CI=9.28, 9.53; p<0.001). For every standard deviation change in shoulder external rotation, a 1.22 Nm change in elbow varus torque occurred (95%CI=1.06, 1.39; p<0.001).

Changes in arm speed have the largest effect on elbow varus torque in adolescent baseball players. Findings from this investigation suggest that elbow torque could be reduced by reducing arm speed and therefore decreasing potential injury. Further research should investigate ways for adolescent players to decrease arm speed while maintaining ball speed.
Research Project Title: Hamstrings-quadriceps ratio is not correlated with sagittal plane knee kinematics

Student Presenter: Deborah Lee

Faculty Mentor: Stephanie Di Stasi

Faculty Mentor Department: Physical Therapy

Research Abstract: Anterior cruciate ligament (ACL) rupture is a devastating knee injury that occurs in more than 250,000 people annually in the United States. Despite successful ACL reconstruction (ACLR), only 55% of athletes return to their previous level of activity and are 15 times more likely to sustain an ACL injury than their uninjured counterparts. The ratio of hamstrings to quadriceps strength (H:Q ratio) is a key variable in ACL injury risk assessment as these muscles enhance knee joint stability by controlling rapid knee flexion during dynamic activities. Current research suggests that a “stiff” landing strategy (i.e. decreased knee flexion) places more strain on the ACL, thus, an unbalanced ratio may indicate an increased risk for ACL injury. Thus, we hypothesized that a higher H:Q ratio would correlate with smaller sagittal knee excursion upon landing after a single-leg hop for distance (SLH). 18 patients (7 male, 11 female) post ACLR provided informed consent and underwent strength testing and biomechanical analysis of the SLH. Subjects performed 5 repetitions of knee extension and flexion at 60°/s on both limbs on a Biodex System 4 Isokinetic Dynamometer. Peak flexion and extension torques were used to calculate the H:Q ratio. Sagittal plane knee excursions were captured with a 12-camera motion-capture system with 55 retro-reflective markers. For the SLH, each subject was instructed to jump as far forward as they could and land on the force-plate on the same limb while maintaining balance. The mean of two successful SLH trials for each limb was compared to the H:Q ratios (Pearson’s R; alpha=0.05). The correlations between H:Q ratio and excursion were weak (Involved: r=-0.363, Uninvolved: r=-0.378) and not statistically significant (p≥0.12). In this sample of individuals post-ACLR, H:Q ratio did not correlate with sagittal knee excursion. This contradicts the findings of Walsh et al. who examined this relationship in males and females. Although Walsh et al. did not find a difference between sexes, research suggests females tend to demonstrate a stiffer landing than males. Future research should explore the differences in landing strategy utilized by males and females and the impact it may have on the ACL.
Research Project Title: Static postural control performance between men and women club soccer student-athletes with history of concussion

Student Presenter: Emily Mulkey

Faculty Mentor: James Onate

Faculty Mentor Department: Health and Rehabilitation Sciences

Research Abstract: Introduction/Background: Static postural control performance is commonly evaluated within concussion management. History of concussion and sex are not always considered in static postural control assessment. Although females exhibit greater postural control deficits than males following concussion, limited evidence exists regarding postural control deficits 6 months following concussion. The purpose of this study was to compare the effect of sex on static postural control of individuals with a history of concussion. Methods: Fifteen collegiate club soccer student-athletes (8 males: 20.63Â±1.51 yrs., 1.80Â±0.09 m., 79.37Â±11.66 kg.; 7 females 20.14Â±0.90 yrs., 1.68Â±0.04 m., 66.39Â±6.86 kg.) volunteered to participate. Participants self-reported a history of concussion and have not been diagnosed with a concussion within the last 6 months. Four static double-limbed postural control assessments were completed on a tri-axial force plate: 1) eyes open (EO) on firm surface, 2) eyes closed (EC) on firm surface, 3) EO on foam surface (AirEx medium-density foam pad), and 4) EC on foam surface. Center of pressure (CoP) excursion, anterior-posterior (A/P), and medial-lateral (M/L) root-mean-square (RMS) amplitude were calculated. A one-way ANOVA was run to compare between groups (sex) with alpha level set a priori at 0.05. Results: No significant differences were observed between groups with EO on firm (CoP excursion: F(1,13)=1.20, p=0.29; M/L RMS amplitude: F(1,13)=0.06, p=0.81; A/P RMS amplitude: F(1,13)=1.21, p=0.29) and foam (CoP excursion: F(1,13)=1.91, p=0.19; M/L RMS amplitude: F(1,13)=2.53, p=0.14; A/P RMS amplitude: F(1,13)=0.00, p=0.99) as well as with EC on firm (CoP excursion: F(1,13)=0.01, p=0.96; M/L RMS amplitude: F(1,13)=0.65, p=0.43; A/P RMS amplitude: F(1,13)=0.60, p=0.45), and foam (CoP excursion: F(1,13)=0.19, p=0.67; M/L RMS amplitude: F(1,13)=1.12, p=0.31; A/P RMS amplitude: F(1,13)=0.89, p=0.36). Conclusion: Static postural control performance did not differ between male and female club soccer student-athletes with a history of concussion suggesting postural control at least 6 months following concussion may not be influenced by sex. Static postural assessments may not be sensitive in detecting underlying deficits 6 months following concussion. More challenging assessments to the postural control system should be further investigated. Clinicians should consider additional factors (i.e. participation in high-impact sport) when evaluating long-term static postural control performance.
Research Project Title: The effects of weight on an externally powered hand prosthesis

Student Presenter: Megan Kruze

Faculty Mentor: Ajit Chaudhari

Faculty Mentor Department: Physical Therapy

Research Abstract: The loss of a hand can be detrimental. An externally powered hand prosthesis may restore function and improve quality of life, but little research has been done on these devices. The purpose of this study was to examine how the weight of an object affects the functionality of a myoelectric prosthetic hand. Partial-hand amputees (6 male) performed the Southampton Hand Assessment Procedure (SHAP), which involved the participants moving identical light and heavy objects in a specific pattern while self-timing. Twelve tasks (heavy and light sphere, triangular prism, cylinder, box with tab on the side, small rectangle, large rectangle) were performed with and without the prosthesis. Three-dimensional data were collected at 150 Hz using passive marker motion capture (Vicon). Upper-limb kinematics were statistically analyzed to determine differences in joint range of motion (ROM) between prostheses conditions to determine movement differences between heavy and light object manipulation.

The non-prosthesis condition resulted in several increased ROM during heavy tasks compared to light tasks: sphere (all variables p<0.05), small rectangle (scapula up/downward rotation p=0.03; wrist flex/extension p=0.008). This condition resulted in decreased ROM during the heavy triangular prism task (all variables p<0.05). The prosthesis condition resulted in fewer differences with increased ROM seen in heavy tasks: large rectangle (elbow flex/extension p=0.02; supination/pronation p=0.05), sphere (trunk flex/extension p=0.03). It also demonstrated decreased ROMs in the heavy box task (shoulder adduction/abduction p=0.05; elbow supination/pronation p=0.0009). These findings indicate the prosthesis appeared able to adjust to the task at hand whereas the amputees were required to change their movement strategies without their prosthesis, resulting in severe differences based on object weight. The ability of the prosthesis to adapt may prove beneficial in reducing secondary injuries. Future work will focus on comparing the limb-loss group to two-handed control outcomes to determine how well the prosthesis mimics healthy function.
Research Project Title: Comparative analysis between pediatric and adult cadaveric knee anthropometry

Student Presenter: Jenna Kuczek

Faculty Mentor: Laura Boucher

Faculty Mentor Department: Injury Biomechanics Research Center

Research Abstract: Little data exist on the anthropometry and material properties of pediatric knee ligaments. This is especially true in those under the age of 1 year. Understanding how pediatric knee ligaments develop through childhood into adolescents may be useful for biomechanists and surgeons to improve knowledge on normal growth and development, and to provide insight into relative knee injury risk and specific age-related surgical approaches. The purpose of this study was to compare pediatric knee anthropometry data to published literature to begin addressing the void of information on this topic. Four knees (2 months to 1 year-old) were procured (AlloSource, Centennial, Co), dissected, measured, and photographed. Anthropometry variables collected included widths and lengths of the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), and lateral collateral ligament (LCL). Femoral bicondylar width was also recorded. The pediatric data were then compared to adult cadaveric data from the literature. These data demonstrate that the pediatric ACL mean length (13.48 mm ± 5.35 mm) was 39% of the adult ACL, the pediatric PCL mean length (15.22 mm ± 3.56 mm) was 40% of the adult PCL, the pediatric ACL mean width (6.61 mm ± 1.10 mm) was 60% of the adult ACL, and the pediatric PCL mean width (7.89 mm ± 1.88 mm) was 61% of the adult PCL. The pediatric LCL mean length (23.46 ± 6.64 mm) was 41% of the adult LCL. Pediatric femur bicondylar mean width (38.74 mm ± 10.02 mm) was 46% that of the adult. While our current sample size is small, we can see preliminary evidence that longitudinal growth of the ACL/PCL ligaments may take more time than the thickening of ACL/PCL ligaments. Planned additional study with these pediatric specimens will include ligament tensile strength testing, using a materials testing machine. Future work will focus on expanding our data set in number and age range with this extremely rare tissue, which will lead to better clinical translation and eventual development of a pediatric knee Finite Element model.
Research Project Title: Development of assistive device for climbing stairs

Student Presenter: Anna Lee

Faculty Mentor: Robert Siston

Faculty Mentor Department: Mechanical Engineering

Research Abstract: Stair climbing is an important part of daily life. However, for elderly people, stair climbing is one of the top five most difficult tasks, and the inability to climb stairs leads to a decreased quality of life. Assistive devices provide a way for people who cannot climb stairs to regain their mobility and improve their lives. While there are several assistive devices for climbing stairs on the market, none of these devices address the root cause of why elderly people cannot climb stairs. One way to identify the root cause is through simulations, which make it possible to understand how assistive devices affect muscles and movement during stair climbing. Simulations also allow for several variations of assistive devices to be tested before creating physical prototypes. In this study, I used OpenSim, software that models the human musculoskeletal system, to add ideal, massless assistive devices like springs and motors to simulations of human subjects climbing stairs. After the devices were added, the simulations were determined successful if the subjects used less energy to climb stairs with the device than without the device. While the research is still in progress, initial results showed that a spring at the ankle caused a decrease in the use of muscles at the ankle and an increase in the use of muscles at the thigh during stair climbing. The results of this study can be used to further develop assistive devices to help elderly people climb stairs and ultimately improve their quality of life.
Research Project Title: Landing mechanics differ between limbs in children six months after pediatric anterior cruciate ligament reconstruction

Student Presenter: Samantha Schilling

Faculty Mentor: Laura Schmitt

Faculty Mentor Department: Health and Rehabilitation Sciences - Physical Therapy

Research Abstract: The incidence of pediatric anterior cruciate ligament (pACL) injuries has increased dramatically in recent years prompting the development of innovative surgical procedures that aim to restore joint stability while avoiding disturbance of open physeal plates. Although postoperative movement mechanics have been extensively studied in the skeletally mature population, little is known regarding movement mechanics in the skeletally immature population following pACL reconstruction (pACLR). The purpose of this study was to examine knee joint kinetic and kinematic variables during the landing phase of a drop-vertical jump (DVJ) task in young athletes six months post-pACLR. 6 participants (all male; mean age: 11.4±1.99 years; mean body weight (BW): 43.4±10.8 kg) were evaluated six months after primary, unilateral, epiphyseal-sparing pACLR (100% iliotibial band autograft). Three-dimensional biomechanical data were collected using a 12-camera system synchronized with two embedded force plates during a bilateral DVJ. Beginning on a 31-cm box, participants were instructed to drop off the box, land with each foot on a separate force plate, and immediately perform a maximal vertical jump. Data were collected during the initial landing phase, which was defined as the point of initial contact with the force plates to the point of lowest center of mass. Peak knee flexion angles, peak internal knee extension moments, and peak vertical ground-reaction forces (normalized to BW) were calculated for the involved (INV) and uninvolved (UNV) limbs using Visual 3D software. Differences between limbs were evaluated using paired t-tests (ðδ=0.05). The involved limb demonstrated a decreased vertical ground-reaction force (mean ± std. dev.; INV: 1.77±0.46 %BW, UNV: 2.28±0.17 %BW, p≤0.05) compared to the uninvolved limb. No statistically significant differences were observed in peak knee flexion angles or internal knee extension moments between limbs (both p>0.05). Children six months post-pACLR exhibit asymmetries in knee loading between limbs during a drop-vertical jump task, demonstrating preference for the uninvolved limb during a functional performance measure. Landing asymmetries between limbs at the time of return-to-sport following ACLR have been shown to correlate to poor outcomes in the skeletally mature population, thus the current findings demonstrating similar asymmetries warrant further research in a skeletally immature population.
Research Project Title: Analysis of kinematic reaching for infants with neonatal stroke to diagnosis cerebral palsy

Student Presenter: Brooke Ott

Faculty Mentor: Jill Heathcock

Faculty Mentor Department: Health and Rehabilitation Science

Research Abstract: Background: Neonatal stroke (NS) is a leading cause for hemiplegic cerebral palsy (CP), which is a disorder that affects muscle coordination and motor development, typically on one side of the body. In most cases, cerebral palsy is not typically diagnosed until months after the stroke, when they present delays in development or obvious symptoms. Delays in development make it difficult to take advantage of neuroplasticity by beginning rehabilitation younger. However, there has been little analysis to understand the underlying coordination of reaching patterns for infants with NS to determine if there is a difference between infants with NS and typically developing (TD) infants. The purpose of this study is to determine whether cerebral palsy can be identified using kinematic data to measure the average reaching speed and end distance from toy occurring at 2-3 months of age.

Methods: N = 28 infants 2-3 months of age N = 17 with NS and N = 11 with TD participated in this study. A 10-camera motion capture (Vicon) system recorded movements at 120 hz for 3 trials of 30 seconds. Infants sat in a chair with reflective markers placed on their hands to record movement. They were shown a toy at midline to encourage arm movements for each trial.

Result: The mean for the average reaching speed for infants with NS and TD are 150.1 mm/s (standard deviation of 46.19) and 142.3 mm/s (standard deviation of 43.32), respectively. There was no significant difference between the average reaching speed (p=0.453). The end distance from toy for infants with NS and TD are 208.9 mm (standard deviation of 29.39) and 198.9 mm (standard deviation of 42.64), respectively. There was no significant difference between the end distance from the toy (p=0.261). These findings are interesting because asymmetry was expected since the infants with NS suffered a brain lesion.

Conclusions: This study is important because it is consistent with previous clinical findings that infants appear to be asymptotic at 2-3 months of age. In future studies, future trials will be analyzed to determine how the reaching patterns change as the participants get older.
Research Project Title: Inter-rater agreement of the single leg squat using a modified qualitative scoring system

Student Presenter: Bailey Urbach

Faculty Mentor: James Onate

Faculty Mentor Department: College of Health and Rehabilitation Sciences

Research Abstract: Introduction:

Within sports medicine, it is imperative that clinicians have inexpensive and reliable means to quickly assess for potential pathomechanics. The visually rated Single-Leg Squat (SLS) is an inexpensive assessment used by clinicians to assess lower extremity dynamic control and potential risk for musculoskeletal injury. A commonly used grading scale for the SLS is the Qualitative Scoring System (QSS), a nominal scale consisting of 10 criteria. However, recent research has indicated that inter-rater agreement of the QSS was generally weak. It has been proposed to simplify the list to four criteria in an attempt to improve inter-rater agreement. The purpose of this study was to determine inter-rater agreement of the SLS using this four criteria scoring system.

Methods:

Thirty male collegiate lacrosse players (19.80±1.15 years, 1.81±0.07 m, 84.14±8.61 kg) performed the SLS on each leg, resulting in 60 SLS performances. A four criteria scoring scale was used by the raters to evaluate the SLS. Two Athletic Trainers with experience in rating the SLS and one novice rater were provided with a training presentation followed by a post-training test to standardize training across all raters. Participants evaluated 60 SLS videos upon completion of the training videos. Fleiss’ kappa was used to assess agreement among all three raters for each criterion.

Results:

Fleiss’ kappa agreement for all raters ranged from poor agreement to moderate agreement (k= -0.08 â€“ 0.57). Fleiss’ kappa resulted in poor agreement for arm strategy (k= -0.08) and trunk alignment (k= -0.02), slight agreement for leg stability (k= 0.20), and moderate agreement for knee valgus (k= 0.57).

Conclusions:

The results reveal that the inter-rater reliability of the SLS is generally poor. These kappa values may be impacted by ambiguity in the application of the criteria when determining if an error is present. By more clearly defining the criteria, it may be possible to increase inter-rater agreement. Further research would better determine the inter-rater agreement of the SLS using the more clearly defined error criteria.
Research Project Title: Lateral pelvic and trunk movement during single leg squat and its relationship to peak knee valgus during single leg hop

Student Presenter: Jack Reifenberg

Faculty Mentor: Jimmy Onate

Faculty Mentor Department: Health and Rehabilitation Sciences

Research Abstract: Knee valgus has been indicated as a primary risk factor for anterior cruciate ligament (ACL) injury. While this may be caused by a lack of knee strength, recent research suggests postural instability may also play a significant role in poor knee control. The single leg squat (SLS) assessment is often used by clinicians to assess postural control as it pertains to lower extremity pathomechanics, however the relationship between SLS mechanics and knee control during a dynamic landing activity is unknown. The purpose of this study was to determine the association between pelvic and trunk movement during a single leg squat (SLS), and knee valgus during an anterior single leg hop for distance (SLHOP) landing. Five male collegiate basketball players (20.4±2.6 years; 197.6±10.7 cm; 102.6±24.6 kg) were recorded using a 3D optical motion capture system (Vicon, Oxford, UK) and synchronized force plates (Bertec, Corp, Worthington, OH) while performing three consecutive SLS, followed by three successful SLHOP trials. Peak knee valgus angle was determined during SLHOP landing from contact until the participant was stabilized. For the SLS, pelvis and trunk displacement in the frontal plane were measured throughout the trial as an indicator of pelvic and trunk control. Spearman rank correlations were run comparing knee valgus during the SLHOP to lateral pelvic and trunk displacement during the SLS, with an alpha level set a priori at p=0.05. Knee valgus during SLHOP landing was not significantly correlated with lateral trunk movement (r = 0.47, 95%CI = -0.21, 0.91, p = 0.18) or lateral pelvic movement (r = 0.60, 95% confidence interval [CI] = -0.093, 0.99, p = 0.073). These results suggest that static postural instabilities are not a significant contributing factor of dynamic knee valgus. However, these findings could be the result of the relatively small sample size. Further research should be conducted with a larger sample size.
Research Project Title: A limb-to-limb comparison of frontal plane hip and knee kinematics after anterior cruciate ligament reconstruction

Student Presenter: R. Garrett Yoder

Faculty Mentor: Stephanie Di Stasi

Faculty Mentor Department: Ohio State Sports Medicine

Research Abstract: Authors: R. Garrett Yoder, Rachel Tatarski, Albert Chen, Timothy E. Hewett, and Stephanie Di Stasi

Approximately 250,000 anterior cruciate ligament (ACL) ruptures occur in the United States annually (1). Those who suffer from this injury are ten times more likely to develop early-onset degenerative knee osteoarthritis (2). Despite ACL reconstruction (ACLR), these individuals are at a high risk for a second ACL injury (2). This increased risk is likely due to abnormal and asymmetric movement patterns at the hip and knee (3). While current standard physical therapy aims to resolve functional performance asymmetries, kinematic asymmetries are often observed at the hip and knee. Thus, the hypothesis tested was that even after standard-of-care treatment, subjects would demonstrate greater frontal plane hip and knee motion of the involved limb during a single-leg hop (SLH) task. In this study, 18 patients (11 female, 7 male; age, 18.9±4.7 years) who were 9.4±4.4 months post-ACLR gave informed consent and underwent 3D biomechanical analysis during SLH. Subjects were instructed to hop as far forward as possible, land over the force-plate on the same limb, and maintain balance; the task was performed on both limbs. Frontal plane kinematics of the hip and knee were derived from a 12-camera motion-capture system using 55 retro-reflective markers during the landing phase of SLH. Independent t-tests were used to compare the mean hip and knee excursions, and peak hip and knee angles of both limbs (p £0.05). No significant differences were found between limbs for hip excursion (involved 16.17±4.06, uninvolved 14.28±5.00, p=0.223) or peak hip adduction angle (involved 6.84±6.61, uninvolved 3.73±4.91, p=0.119). No significant differences were found between limbs for knee excursion (involved 5.34±1.65, uninvolved 5.63±1.98, p=0.638) or peak knee abduction angle (involved 4.87±2.63, uninvolved 4.42±2.30, p=0.589). Although contrary to our hypothesis, these findings are consistent with previous work that demonstrated no differences in hip or knee angles between limbs in a female cohort (4). However, the present study grouped males and females together, which may mask potential sex-based differences present in this population. Females often utilize a quadriceps-dominant activation pattern compared to males, which has been associated with ACL injury (5). Future studies should investigate sex-specific landing strategies after ACLR and risk of secondary ACL injury.


Research Project Title: Development of a custom MATLAB code to quantify the material properties of ribs

Student Presenter: Scott Stuckey

Faculty Mentor: Amanda Agnew

Faculty Mentor Department: School of Heath and Rehabilitation Sciences

Research Abstract: Thorax injuries, particularly rib fractures, are prevalent in motor vehicle crashes, and have a high instance of morbidity and mortality. As the rib cage provides much of the protection to the thorax, it is important to understand the behavior and material properties of human ribs. The purpose of this project was to develop a method to quantify the material properties of individual ribs by creating stress-strain curves. Consequently, 335 whole mid-level ribs from 170 post-mortem human subjects were tested individually in a dynamic loading scenario to failure. Strain, force, and moment data were collected during the tests, using uniaxial strain gages and a 6-axis load cell, respectively. A custom MATLAB code was developed to create stress-strain curves for each rib and evaluated on a subsample of 11 rib tests. Stress was calculated using straight beam theory for a discrete cross-section adjacent to the fracture site. The cortical area and the section moduli for both pleural and cutaneous cortices of the rib were determined using ImageJ software on histological high-resolution images of each cross-section. TEMA motion tracking software was used to determine the location and local displacement of various points on the global geometry of the rib throughout the duration of the tests. These data were used to create a polynomial model of the rib with \( R^2 \geq 0.99 \), thus the stress values were calculated with a high degree of accuracy. Stress was calculated using angles calculated from the polynomial fit of the rib by determining the arctangent of the slope at the location of the histological cross-section. Using these data, stress-strain curves for the discrete section were created for each of the 11 ribs. This novel method can successfully and more accurately derive stress-strain curves. Additionally, using these curves, material properties (e.g., modulus, ultimate stress, etc.) can be quantified from structural tests representing realistic rib behavior in a frontal crash. Calculation of properties for all 335 tested ribs will be important to better understand variability in human rib response and injury thresholds in order for the properties to be utilized to increase the biofidelity of vehicle occupant finite element models.
Research Project Title:

Student Presenter: Mary McGrath

Faculty Mentor:

Faculty Mentor Department:

Research Abstract:
Research Project Title: The relationship between structural properties in anterior-posterior loading and material properties in coupon testing of human ribs

Student Presenter: Akshara Sreedhar

Faculty Mentor: Amanda Agnew

Faculty Mentor Department: Health Sciences

Research Abstract: Thorax injuries, e.g. rib fractures, are common in motor vehicle crashes (MVC), leading to high morbidity and mortality rates. Numerical simulations of occupants in MVCs requires precise computational models of the thoracic skeleton to accurately simulate response and assess injury risk. The goal of this study is to determine relationships between structural and material properties of human ribs from two testing methods.

Three-hundred thirty two mid-level ribs from 173 post-mortem human subjects were tested in a dynamic anterior-posterior bending scenario simulating a frontal thoracic impact. Prior to impact, uniaxial strain gages were attached to cutaneous and pleural surfaces of ribs at 30% and 60% of the total curve length. After impact, normalized percent displacement was calculated as anterior-posterior displacement at the time of peak strain, i.e. strain immediately before fracture, relative to the original length of the rib. Results showed a significant (p<0.0001) linear relationship between peak strain and global displacement. Exploring this relationship assisted in calculating a yield-displacement (4.83%) for assessing structural response equivalent to the 0.2% offset method utilized for assessing yield from stress vs. strain curves.

Twenty-nine 6th rib pairs were selected for direct comparison of material and structural properties. One side was tested in the whole rib experiment for structural property calculation, while the contralateral side provided cortical bone coupons for tension testing and material property calculation. Structural properties, e.g., structural stiffness, yield force, and energy, were calculated from force vs. displacement curves, while material properties, e.g., modulus, yield stress, and strain energy density, were calculated from stress vs. strain curves. The relationship between analogous structural and material properties reveals statistically significant positive correlations for all comparisons (p<0.05), indicating that material properties have an influence on structural properties. However, further investigation is necessary to quantify other contributions to structural response (e.g., geometric properties).

The results from this study are crucial to advancing finite element human body models by improving the accuracy by which the material and structural properties of ribs are modeled and how they contribute to overall thoracic response and injury tolerance. These advancements will aid in the reduction of thoracic injury risk during MVCs.
Research Project Title: Design and implementation of a new biofidelic ATD neck for rear impacts

Student Presenter: Jonathon Blank

Faculty Mentor: Yun Seok Kang

Faculty Mentor Department: Health and Rehabilitation Sciences

Research Abstract: Anthropomorphic test devices (ATDs) are intended to provide a humanlike response in experimental scenarios where using human volunteers or post-mortem human surrogates (PMHS) are either inappropriate or impossible. Therefore, an effective ATD must be biofidelic, meaning that it must replicate the response of a human in an automotive impact. A current regulation allows for the use of the Hybrid III ATD in rear impacts although it was designed for frontal impacts only, and the ATD’s neck has been found to exhibit poor biofidelity in this scenario. One of the more biofidelic rear impact necks, the BioRID II, only allows for 2D sagittal plane motions due to its use of revolute joints between each pair of cervical vertebrae. The purpose of this study is to provide a new biofidelic, mechanical design for an ATD neck that allows more degrees of freedom, making it more representative of a human’s neck and therefore more biofidelic. The neck’s design is intended to anatomically replicate a human neck and includes seven individual vertebrae. Spherical joints were used in between these vertebrae, with the exception of the C1 and C2 revolute coupling, thus accommodating more degrees of freedom. Four strands of wire rope, two anterior and two posterior, in combination with polymer damping material, were utilized in the design to control the kinematics of the neck. Dynamic simulations using a commercial multibody dynamics software (e.g. MSC ADAMS) were conducted in order to validate the design’s biofidelity by mimicking the results of previous rear impact PMHS research conducted at the Injury Biomechanics Research Center. Damping material and wire ropes were modeled using two and one-way spring dampers, respectively. The resulting ATD neck is the product of a novel design process with the objective of improving biofidelity. The neck will ultimately help to increase occupant safety in rear-end automotive collisions as it will provide car manufacturers with a more humanlike tool from which they can base future car safety design features.
Research Project Title: Stroop and single-leg balance dual task paradigm

Student Presenter: Katie Jira

Faculty Mentor: James Onate

Faculty Mentor Department: Health & Rehab Sciences

Research Abstract: Although clinical assessments evaluate performance via single-task (ST) paradigms, daily activities integrate motor and cognitive tasks concurrently rather than independently. Therefore, dual-task (DT) paradigms may better reflect overall performance. Stroop tests are often implemented to evaluate selective attention, but different versions exist that may elicit differences in cognitive performance. A better understanding of cognitive performance under DT using various Stroop tests is warranted. The purpose of this study was to determine if differences in cognitive performance existed between ST and DT paradigms when performing different Stroop tests. Eighteen healthy college students (five males, 21±0.25 yrs., 168.63±2.26 cm, 64.914±2.57 kg) volunteered. Participants performed two forms of the Stroop test: 1) Stroopsingle: a single color-word stimulus presented every two seconds for 48 seconds and 2) Stroopmultiple: 24 color-word stimuli presented at the same time. Both Stroops were performed under ST (independently) and DT (concurrently with single-leg balance) on a tri-axial force plate (Bertec Corporation, Columbus, OH). ST was completed prior to DT for all participants. Stroop tests consisted of congruent (font color matches the color-word) and incongruent (font color does not match the color-word) stimuli. Participants verbalized the color of the color-word. The number of correct congruent and incongruent responses were recorded and calculated as a percentage of total responses (ResponseC and ResponseI, respectively). Comparisons of Stroopsingle and Stroopmultiple were analyzed independently. ResponseC was not different between ST (99.90±0.44%) and DT (99.59±1.75%) with Stroopsingle (p=0.48) and for ResponseC between ST (98.88±3.23%) and DT (99.81±0.79%) with Stroopmultiple (p=0.135). No differences were observed for ResponseI between ST (98.46±0.48%) and DT (98.87±0.37%) with Stroopsingle (p=0.30) and for ResponseI between ST (98.41±0.61%) and DT (98.68±0.58%) with Stroopmultiple (p=0.76). No cognitive performance differences were observed between ST and DT for both Stroop tests. The balance task may not be challenging enough to the system to influence changes in cognitive performance. Cognitive DT deficits have been reported in those following injury, i.e. concussion; therefore, pathological populations should be investigated to determine if different Stroop tests elicit changes in performance. Clinicians should consider incorporating DT into evaluations with appropriate motor and cognitive tasks to comprehensively assess functional and cognitive performances.
Research Project Title: The use of injury severity scoring systems to predict treatment processes, costs, and outcomes of spinal trauma patients

Student Presenter: Dinushi Kulasekere

Faculty Mentor: Bruce Weinberg

Faculty Mentor Department: Economics

Research Abstract: Econometric analysis of retrospective scoring systems used in clinical care is a relatively under-studied topic in both the economics and medical literature. This project develops an approach to understand the potential impact of data gathered through retrospective severity scoring methods and how it can be used to better understand costs and outcomes in a healthcare setting, with a focus on spinal injury severity classification systems. A multiple regression analysis of dependent variables including hospital cost and treatment process indicators, such as time to operating room, time to CT scan, time to discharge, discharge destination, and mortality, will be conducted. Independent variables will include Injury Severity Scores and Abbreviated Injury Scale values to determine if expenditure, treatment process indicators, and/or patient outcome can be predicted using an econometric model. Furthermore, an analysis of delays to treatment and their impact on hospital cost will be studied. Secondary, de-identified hospital data will be provided by the Midland Trauma Research Center of New Zealand’s Waikato District Health Board.

Understanding the predictive value of these scaling systems could influence the quality of care for patients world-wide with respect to the general usage of health-related classification systems in the medical field, including within the field of cancer research. The Gleason Score is a specific example of a cancer-focused classification system used to classify the severity of prostate cancer, which uses a computation method similar to the Injury Severity Score used in trauma classification. The goal of this project is to determine the potential implications of using classification systems to answer questions related to cost and outcome efficiency, providing evidence to either support or refute the usage of these scales in assessing care pathways in the medical field. Regardless of the results, this research will showcase the benefit of using econometric techniques to answer questions related to clinical care, highlighting a unique approach to achieving better efficiency and outcomes in health care systems. Data analysis is ongoing and results will be discussed at the presentation.
Research Project Title: Development of a modular ankle-foot orthotic

Student Presenter: Alivia Lahr

Faculty Mentor: Robert Siston

Faculty Mentor Department: Mechanical and Aerospace Engineering

Research Abstract: An ankle-foot orthotic (AFO) is a rigid brace used to support the ankle joint by mechanically compensating for muscle weakness. Conventional manufacturing methods consist of two types of AFOs: pre-fabricated and custom cast polypropylene. Pre-fabricated devices are low cost ($60) and available off-the-shelf in a limited number of sizes and geometries. Custom cast AFOs are expensive ($750-$1000) and require a lengthy manufacturing process. However, due to the diversity of the patient population and the resulting complexity of fit, support, and force application requirements, custom cast AFOs are required in 82% of cases. The purpose of this study is to design a low cost, modular AFO that can be easily customized in size, support, and force application using a set of mass-produced components. The literature review provided information on device failure, such as points of stress concentration, and patient support requirements that were used to create a novel process for the development of interchangeable AFO components. SolidWorks force analysis software and ANSYS, finite element analysis software, will be used to design the modular components for a prototype. The modular AFO prototype will be tested and compared to pre-fabricated AFOs for ease of assembly, patient fit, and effectiveness of gait correction. The results of this study can be used in the future for the design of highly customizable, inexpensive, modular assistive devices. The modular AFO design will greatly improve the quality of life and reduce the financial burden on patients requiring custom AFOs.
Research Project Title: Lower extremity strength does not correlate with sagittal plane knee mechanics during single leg hop landing in obese youth

Student Presenter: Claire Spech

Faculty Mentor: Matt Briggs

Faculty Mentor Department: Department of Orthopedics, Sports Medicine Research Institute

Research Abstract: Obese (OB) youth show lower relative lower extremity (LE) strength and altered knee mechanics during dynamic activities compared to healthy weight (HW) youth. Understanding the associations between LE strength and knee mechanics will help guide physical activity recommendations for OB youth. The purpose of this study was to evaluate the associations between LE muscle peak torque with knee kinematic and kinetic variables during a single leg hop (SLHop) landing. Twenty-five OB (age: 14.16±1.99, 17 male/8 female, BMI 95th percentile<99th percentile) were recruited and age and sex matched to twenty-five HW (age: 14.24±1.96, 17 male/8 female, BMI 5th-<85th percentile) youth. Isokinetic knee extension (KneePT) and isometric hip extension peak torque (HipPT) were measured on the dominant limb. Peak torque was normalized to lean leg mass (Nm/Kg). Using 3D motion analysis, peak internal knee extension moment (Nm/m*kg) and maximum knee flexion angle (degrees) were measured during the first second of landing from a SLHop. Paired T-tests and Pearsons correlation coefficients were used for hypothesis testing. OB youth were weaker compared to the HW group (KneePT, OB: 12.68 ±1.36, HW: 14.10±2.04, p=0.026; HipPT, OB: 8.72±3.14, HW: 11.02Â±2.43, p=0.027). The OB group landed with decreased peak knee flexion angles (OB: 48.7Â±9.88, HW: 56.07Â±7.53, p=0.021) and peak internal knee extension moments (OB: -1.74Â±0.42, HW: -2.21Â±0.39, p=0.00). HW HipPT was correlated with maximum knee flexion angle during landing (r=0.438, p=0.032), whereas the OB group showed no significant correlation (r=0.354, p=0.115). There were no significant correlations in either group between KneePT and maximum knee flexion angle at landing, KneePT and peak internal knee extension moment, or HipPT and peak internal knee extension moment (p>0.05). In summary, OB youth demonstrated lower LE peak torque than HW youth. There was no correlation between LE strength and landing mechanics in OB youth, while HW youth demonstrated a moderate positive correlation between HipPT and maximum knee flexion angle at landing. These results suggest other factors, such as strength of other LE muscles, trunk control, and confidence may influence landing knee mechanics in OB youth. Future studies should assess other comprehensive factors that may contribute to SLHop performance and knee mechanics.
Research Project Title: BabyCHAMP: a preliminary analysis of movement patterns in children with hemiparesis

Student Presenter: Emily Young

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Research Abstract: Emily Young, Brooke Ott, Meredith Schram, Amy Darragh, PhD, OTR/L, Jill Heathcock, PhD, PT, Andrew Persch, PhD, OTR/L, Stephanie DeLuca, PhD, and Sharon Ramey, PhD

Introduction: Constraint-induced movement therapy (CIMT) is a highly effective nonsurgical treatment for children with cerebral palsy (CP). However, there is limited evidence that CIMT is effective for infants and toddlers and although several randomized controlled trials (RCT) currently are underway, these results are not yet available. The BabyCHAMP (Children with Hemiparesis Arm Movement Project) Study is a RCT of CIMT for children with unilateral (hemiparetic) spastic CP or asymmetrical CP between 6 and 24 months of age. The purpose of this study is to test the efficacy of ACQUIREc, an intensive therapy designed to improve UE function in children with CP, across 3 different constraint conditions (continuous - full time cast; part-time “splint; and no constraint) as measured by change in the child’s UE motor performance.

Methods: In addition to standardized observational measures of motor performance (Bayley Scales of Infant and Toddler Development and the Mini-Assisting Hand Assessment), kinematic assessments of a standardized reaching protocol are performed. Assessments include 30-second trials of various scenarios to induce unilateral and bilateral reaching. A toy was held to prompt these reaching patterns and movements were recorded using reflective markers and a VICON MX “F40 motion-capture system.

Results/Conclusion: Preliminary analyses revealed that participants move their affected UE fewer times (8.36 +/- 9.04 and 10 +/- 10.20) than their less affected (16.18 +/- 9.64 and 29.33 +/- 22.51) when a small toy (maraca) or a large toy (beach ball), respectively, was present and both arms were available. Additionally, kinematics of average movement length, average movement speed, and peak velocity of the movements were quantified. For the maraca affected UE and less affected these were respectively: 53.64 +/- 14.54 and 63.43 +/- 18.76mm; 137.18 +/- 55.57 and 203.44 +/- 125.62mm/sec; and 270 +/- 96.56 and 425.70 +/- 190mm/sec. For the beach ball affected UE and less affected they were respectively: 59.16 +/- 17.58 and 79.71 +/- 32.75mm; 258.45 +/- 177.68 and 334.76 +/- 176.25 mm/sec; and 456.99 +/- 274.85 and 626.51 +/- 283.21mm/sec. This is one of the first quantified comparison of amount and kinematics of reaching in infants and toddlers with hemiplegia.