



College of Engineering

11th Annual

Biomechanics Research Symposium

April 21, 2014

Center for Biomechanical Engineering Research

201 Spencer Lab | Newark, Delaware 19716 | www.cber.udel.edu

Welcome students, faculty and friends!

It's my pleasure to welcome you to the 11th annual CBER day research symposium - my first as the newly-appointed director of the center - and I look forward to seeing friends and colleagues, new and old, and making new acquaintances. As in years past, this symposium puts on display the excellent Biomechanical research being conducted by the students, faculty and research professionals at the University of Delaware.

I am especially pleased to announce that our keynote speaker this year is Dr. Alberto Esquenazi, MD. Dr. Esquenazi is the John Otto Haas Chair of the Department of Physical Medicine and Rehabilitation at Albert Einstein Medical Center, Chief Medical Officer of MossRehab/Einstein, as well as holding numerous other positions at institutes in the southeastern Pennsylvania region. He will speak on the impact and some of the potential obstacles associated with careers in Biomechanics and Bioengineering.

As we continue to celebrate the interdisciplinary and collaborative spirit upon which CBER was founded, I welcome your help and participation in moving the center forward, and navigating the new challenges ahead. I would also like to acknowledge support from the Delaware Rehabilitation Institute, which sponsored the student awards presented at the conclusion of today's events.

Thank you all for your part in making today another successful CBER day research symposium.



ACKNOWLEDGEMENTS

ORGANIZING COMMITTEE

- Michael H. Santare
- Elaine Nelson
- Jill Higginson

STUDENT COMMITTEE MEMBERS

- Amy Bucha
- Andrea Di Trani
- Matthew Failla
- Aaron Struminger
- Melissa Torres
- Laura Van Der Post
- Elizabeth Wellsandt

All student awards are sponsored by the Delaware Rehabilitation Institute

Keynote Lecture

"Biomechanics, a window into Medicine"

Alberto Esquenazi, MD



Biomechanics has been linked to the medical sciences since its origins, in my opinion Leonardo da Vinci could be recognized as the first biomechanician because he was the first to study anatomy in the context of mechanics. He analyzed muscle forces acting along lines connecting origins and insertions and studied joint function. He also intended to mimic some of these features in many machines he designed. One example, was the study of birds during flight in his search to find means to help humans fly. The study of biomechanics ranges from the inner workings of a cell to the movement and development of limbs, to the mechanical properties of soft tissue, and bones. In this presentation my aim is to showcase how your chosen carrier path has positively impacted the lives of many

in the field of rehabilitation medicine, also to point at concepts where communication was not clear and the development had limited application or was rejected. The presentation will make use of examples where bioengineering was applied to improve care or has played a key role in developing substitutes to improve human function and maybe plant small seeds for new ideas. I hope to encourage you to collaborate with others in medicine, the potential users and engineering to further advance what is possible as new technology becomes available.

BRIEF BIOGRAPHY

Dr. Esquenazi received his medical degree in Medicine and Surgery from Universidad Nacional Autonoma (the National Autonomous University of Mexico), in Mexico City. He completed his residency in physical medicine and rehabilitation at the Temple University / MossRehab program in Philadelphia, and a fellowship in gait analysis and prosthetic research at MossRehab. Dr. Esquenazi's research focuses on gait analysis, limb prosthetics, orthotics, and spasticity management. From his extensive knowledge, he has developed electronic educational programs on functional anatomy, spasticity, and muscle overactivity. Dr. Esquenazi has published widely in peer reviewed journals and has authored more than 40 book chapters. His research in spasticity management, gait, orthotics, and limb prosthetics has led him to be an invited speaker at national and international events. Dr. Esquenazi is a member of many national and international professional, educational, and research societies and review pannels, including Chairing the National Advisory Board on Medical Rehabilitation Research of the National Institute of Child and Human Development of the National Institutes of Health. He is Past-President of the American Academy of Physical Medicine and Rehabilitation and a member of the board of the International Society of Rehabilitation Medicine. He is the recipient of prestigious national and international awards for his clinical, research and educational efforts and has been recognized for several years among "Top Doctors" in *Philadelphia* magazine and *America's Top Doctors*.

Schedule of the Day

TIME	WHAT	WHERE
8:30	BREAKFAST & POSTER SET-UP	STAR CAMPUS- GLASS ATRIUM
9:00	WELCOME & INTRODUCTORY REMARKS	STAR CAMPUS- GLASS ATRIUM
9:15	PODIUM SESSION 1	STAR CAMPUS- GLASS ATRIUM
10:45	BREAK	
11:00	POSTER SESSION 1 (ODD #S)	STAR CAMPUS- MAIN CONCOURSE
12:00	LUNCH	STAR CAMPUS- ATRIUM CONFERENCE ROOMS: 110, 111 & 113
1:00	KEYNOTE: DR. ALBERTO ESQUENAZI	STAR CAMPUS- GLASS ATRIUM
2:00	POSTER SESSION 2 (EVEN #S)	STAR CAMPUS- MAIN CONCOURSE
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4:30	AWARDS SESSION	STAR CAMPUS- GLASS ATRIUM

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- 6** P.12 PEAK MEDIAL COMPARTMENT CONTACT FORCES (PMCCF) IN THE KNEE AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION (ACLR) – 5 YEAR FOLLOW UP
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- 4** P.15 VISION BASED RAPID MODELING OF PERSONALIZED REHABILITATION DEVICES
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- 5** P.16 ASSOCIATION OF JOINT MOMENTS AND CONTACT FORCES WITH EARLY KNEE JOINT OSTEOARTHRITIS AFTER ACL INJURY AND RECONSTRUCTION
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- 6** P.16 DYNAMIC STABILITY DURING DUAL-TASK TREADMILL WALKING IN HEALTHY ADULTS
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PODIUM PRESENTATIONS

Session 1

1 WALKING SPEED AND STEP LENGTH ASYMMETRY MODIFY WALKING ECONOMY AFTER STROKE

Louis Awada; Jacqueline Palmera; Stuart Binder-Macleoda,b; Ryan Pohligb; Darcy Reisman

- a) Graduate Program in Biomechanics and Movement Science
b) Delaware Clinical and Translational Research Accel Program

A higher energy cost of walking poststroke has been linked to reduced walking performance and participation in the community. To inform future rehabilitation efforts and facilitate the development of targeted gait interventions, this investigation sought to identify gait deficits that, when improved, result in less energy expended during walking. Specifically, the contribution of improvements in walking speed and spatiotemporal gait asymmetry to the reduction of poststroke walking economy after intervention were tested. Methods: 42 subjects with chronic stroke were recruited to participate in 12 weeks of walking rehabilitation. Walking economy and speed, as well as step length, swing time, and stance time asymmetries were calculated pre- and posttraining. Sequential linear regression analyses tested the cross-sectional (ie, pretraining) and longitudinal (ie, posttraining changes) relationships between walking economy versus walking speed and each measure of asymmetry. Secondary analyses were conducted to determine the influence of pretraining asymmetry on this relationship. Results: Pretraining walking speed ($\beta = -.506$) and swing time asymmetry ($\beta = .403$) predicted pretraining walking economy ($\text{adjR}^2 = .713$, $F(37,3) = 34.05$, $p < .001$). Change in walking speed ($\beta = .338$) and change in step length asymmetry ($\beta = .533$) predicted change in walking economy ($\text{adjR}^2 = .447$, $F(33,3) = 10.7$, $p < .001$), but change in swing time asymmetry did not. Moderation of this model by the direction or magnitude of pretraining asymmetry was not present. Conclusions: These findings suggest that poststroke interventions that target deficits in walking speed without regard for walking asymmetry may be inadequate to produce optimal improvements in walking economy.

2 MOVEMENT ASYMMETRIES DURING SIT TO STAND TASK BEFORE AND AFTER TOTAL HIP ARTHROPLASTY

^{1,2}Sumayah Abujaber, ²Federico Pozzi, ²Joseph Zeni Jr.

- ¹ University Of Jordan, Amman-Jordan,
²University of Delaware, Newark-Delaware

Total hip arthroplasty (THA) effectively manage pain and improve function in patients with end-stage hip osteoarthritis. However, patients after THA demonstrate movement asymmetries in various motor tasks. During sit to stand (STS) task, patients rise from a chair with general unloading of the operated side and shifting the weight to the non-operated side, and with reduced motion and moments in the operated hip joint. However, outcome studies that have analyzed the STS biomechanics in the THA population were cross sectional studies. The pre- to postsurgical biomechanical changes after THA have not been evaluated.

To determine how THA changes the biomechanics of STS task. Therefore we aimed to identify the interlimb movement differences during STS performance before and after THA, and to document the pre- to postsurgical biomechanical changes in each limb.

Twelve subjects scheduled for unilateral THA completed 3-dimensional motion testing during STS task, 2-4 weeks before and 3 months after THA. Average vertical ground reaction force (VGRF), peak hip flexion moment (HFM), and peak knee flexion moment (KFM) were computed for each limb.

Before THA, interlimb differences were found in all variables. Preoperative interlimb differences in all variables showed considerable improvement by 3 months after surgery exemplified by significant increases in the KFM in the operated limb and reduced VGRF in the non-operated limb. However, interlimb differences in VGRF and KFM still persisted after THA.

THA improves movement symmetries during STS performance, but doesn't completely restore symmetrical movement. These results emphasize the need for investigating the factors that contribute to persistent movement asymmetry, which will lead to develop targeted rehabilitation to maximize movement symmetry after THA.

3 EVALUATION OF TENDON INJURIES USING VISCOELASTIC PROPERTIES MEASURED VIA ULTRASOUND IMAGING: PRELIMINARY RESULTS.

Daniel Cortes¹, Stephen Suydam², Karin Silbernagel³, Thomas Buchanan², Dawn Elliott¹.

- ¹Biomedical Engineering, University of Delaware
²Mechanical Engineering, University of Delaware
³Physical Therapy, University of the Sciences

Tendon injuries, such as tendinopathy or rupture, often result in decreased mechanical properties and abnormal collagen-fiber structure. Since tendon structure and composition are difficult to quantify non-invasively, changes in viscoelastic properties can be used as equivalent biomarkers of tendon health and function. The objectives of this study are to develop a method for the measurement of viscoelastic properties of tendons (continuous Shear Wave Elastography, cSWE), to validate cSWE by comparing measurements of wave speed with those obtained using Magnetic Resonance Elastography (MRE), and to present preliminary measurements in human Achilles tendons in-vivo. The viscoelastic properties (σ : elasticity, and η : viscosity) were calculated using the Voight model. Comparison of wave velocity measurements between sSWE and MRE showed an excellent agreement for agarose gels of different concentrations (1%, 1.5% and 2%). Preliminary data on healthy volunteers ($n = 7$) showed that it is feasible to measure the viscoelastic parameters in the middle portion of the Achilles tendon. A strong viscoelastic effect was observed for the Achilles tendon for which the shear wave speed increased 2-fold when the vibration frequency was increased from 200 to 600 Hz. The viscoelastic properties at the middle portion of the tendon were $\sigma = 71.7 \pm 49.2$ kPa and $\eta = 64.6 \pm 13.3$ Pa s. The advantage of the proposed technique is that maps of viscoelastic properties of the Achilles tendon can be measured. Therefore, our technique can be used to quantify changes of viscoelastic properties at the tendinopathy lesion and surrounding tissues, to evaluate the healing process of Achilles ruptures, and to compare the effectiveness of different treatments for tendon injuries.

4 FINITE ELEMENT PREDICTIONS OF STRAIN ATTENUATION IN PROTEOGLYCAN-RICH MICRODOMAINS

John DeLucca, Woojin Han, John Peloquin, Randy Duncan, Robert Mauck, Dawn Elliott

The mechanics of fiber-reinforced tissues such as the annulus fibrosus and meniscus are governed largely by highly organized collagen structure. However, recent studies have shown that proteoglycan-rich deposits, or microdomains, that are interspersed within the collagen structure alter the strain transfer from the tissue down to the cells. Specifically, the local matrix within the proteoglycan-rich microdomains (PG μ -domains) experiences significant less strain compared to the fibrous region of the tissue, resulting in a heterogeneous strain field. It remains unknown how the structure-function relationships in the tissue result in the observed heterogeneous strain fields and what the associated stresses are. The objectives of this study were to implement PG μ -domains into a finite element model, compare with experimental data, and determine the strain fields at multiple physiological loading levels.

Strain transfer from the tissue level to the local matrix level was taken from our recent experimental studies. A histological image was used to determine a representative shape of the PG μ -domains for the finite element model. Using a custom MATLAB code, the finite element model with PG μ -domain was implemented in FEBio, an open source software package developed for biological tissue modeling. A Holmes-Mow matrix with fibers that follow an exponential power-law was used to represent the fibrous domain, and a Holmes-Mow matrix with no fibers but with an osmotic swelling component was used to model the PG μ -domain.

The finite element model produced 30-40% strain attenuation in the PG μ -domains as compared to the fibrous region, which was consistent with the mechanical testing data. These results have important implications in the mechanobiology of fibrous soft tissues, as cells will respond according to the mechanical signals within their microenvironment.

5 A BIOMECHANICAL-BASED MODEL FOR PREDICTING PROPULSIVE FORCES DURING ABLE-BODIED GAIT

HaoYuan Hsiao¹, Brian A. Knarr², Jill S. Higginson^{1,3}, Stuart A. Binder-MacLeod^{1,4}

¹Biomechanics and Movement Science Program

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⁴Department of Physical Therapy, University of Delaware

Current rehabilitation for individuals post-stroke focuses on restoring walking ability because it is strongly correlated with quality of life. A major factor required for translating the body forward during normal gait is the ability to generate propulsive force. Previous studies with regression-based model have pointed out the critical factors that are related to propulsive force in both healthy and post-stroke populations: ankle plantar flexor muscle strength and trailing limb angle (TLA). However, these relationships do not provide quantitative information regarding the relative potential of each of these factors to improve the propulsive force. Quantifying the impact of these biomechanical factors on propulsive force during gait would allow for the design of rehabilitation strategies for improving propulsive force in individuals post-stroke. The primary purpose of this study was to develop a mathematical model to quantify the contribution of ankle moment and TLA on propulsive force. Twenty healthy individuals walked at their self-selected and 120% of self-selected walking speed on the treadmill. Independent groups of subjects were used for model development and validation. Using a generic equation for the ankle moment obtained through inverse dynamics analysis, we identified the key clinically accessible parameters that determine propulsive force. Our main findings were (1) Peak ankle moment and peak TLA have similar potential to facilitate peak propulsive force, and (2) Healthy individuals utilize more TLA than ankle moment adjustment to modulate propulsive force. These findings provide a biomechanical basis for the development of targeted pathological gait therapies

6 PEAK MEDIAL COMPARTMENT CONTACT FORCES (PMCCF) IN THE KNEE AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION (ACLR)

– 5 YEAR FOLLOW UP

A. Khandha, E. Gardinier, J. Capin, K. Manal, L. Snyder-Mackler, T. Buchanan

Comparing pMCCF in the involved versus uninvolved limb using a neuromusculoskeletal (NMS) model can confirm whether asymmetric loading and decreased loads prevail after ACLR.

Ten active subjects (5 females, 5 males, Age: 32 ± 12 years) with unilateral knee injuries underwent ACLR, rehabilitation, gait trials and electromyography (EMG) analysis. Kinematic and kinetic parameters were recorded using an 8-camera video system and force platforms respectively. Surface-EMG recordings were collected from the following 7 muscles crossing each knee joint: medial/ lateral vasti, rectus femoris, semitendinosus, long head of biceps femoris, and medial/lateral gastrocnemii. pMCCF were computed using a validated Hill-type EMG-driven NMS model, which was anatomically scaled and calibrated for each subject. pMCCF obtained were normalized to body weight (BW) for each trial. 3 trials per subject were averaged for each limb. Two way analysis of variance was used to examine changes in pMCCF in each limb at three time points (Factors: Limb – Involved/ Uninvolved, Time Points – Baseline/2 years/5 years post-operatively).

pMCCF was significantly lower in the involved limb at baseline (2.34 BW vs. 3.04 BW, $p=0.02$), but this asymmetry did not exist at 2 and 5 years. Also, pMCCF in both limbs were significantly lower at 5 years, compared to the earlier time point ($p=0.04$).

In subjects with a unilateral knee injury, an asymmetric loading pattern was observed prior to surgery. These loading asymmetries did not exist after ACLR and rehabilitation, which is encouraging. However, pMCCF were also lower at 5 years, indicative of unloading. While not directly proven yet, it is possible that unloading may result in cartilage deconditioning, thinning and ultimately OA.

PODIUM PRESENTATIONS

Session 2



1 ONE-DIMENSIONAL SPATIOTEMPORAL IMAGE CORRELATION SPECTROSCOPY-BASED QUANTIFICATION OF MICROFLUIDIC FLOWS

Brian Graham and Christopher Price

Biomedical Engineering, University of Delaware

Fluorescent correlation spectroscopy (FCS) is an imaging approach that has been used successfully to optically measure the convection of fluorescent particles in solution, but has limited applicability to very slow and fast velocities. A novel analogue of FCS, which we term one-dimensional spatiotemporal image correlation spectroscopy (1-D STICS), has the ability to quantify fluorescent particle velocities over a much wider range than FCS.

In 1-D STICS, as opposed to FCS, we repeatedly and rapidly capture a raster-scanned data line within the microfluidic system, creating a data "carpet" in which fluorescent particle transport results in pixel intensity fluctuations. We then perform cross-correlation among different points in the scan using Fourier methods to generate a spatiotemporal correlation map. If, on average, line scanning is performed faster than the time it takes for a fluorescent particle to traverse the length of the scan line, a streak will appear in the correlation map. We isolated streaks from the correlation maps using image segmentation techniques, then used a weighted central moment calculation to calculate streak orientation. From this streak orientation angle, average particle velocity can be calculated. We have verified this methodology by quantifying laminar fluid flow driven by a syringe pump through a rectangular microfluidic-imaging channel. Comparison of our measurements to analytical solutions for laminar channel flow showed that 1-D STICS can quantify velocities on the order of $\mu\text{m/s}$ to mm/s . In further work we will incorporate a windowed analysis approach to allow for the measurement of pulsatile or oscillatory fluid flows.

1-D STICS, as well as its image-based extension, 2-D STICS, hold great promise for mapping microfluidic transport in a variety of situations, including microfluidic devices, blood vessels, engineered vascular tissues, and musculoskeletal tissues.

2 KNEE FUNCTIONAL PERFORMANCE (KFP) AND PATIENT-REPORTED MEASURES (PRM) AT SIX-MONTHS AFTER ACL RECONSTRUCTION (ACLR) PREDICTS RETURN TO PREINJURY ACTIVITY LEVEL (RPLA) AT TWO YEARS (2Y) AFTER ACLR

Z.Nawasreh, D.Logerstedt, K.White, L.Snyder-Mackler

The common goal of ACLR is to RPLA. Only 33% of patients have attempted full competition 1y after ACLR. Little is known about which combination of KFP and PRM 6months (6m) after ACLR contributes to the ability to RPLA 2y after ACLR. Therefore, the aim of this study was to determine which KFP and PRM 6m after ACLR predicts RPLA 2y after ACLR.

Sixty athletes who were regular participants in level I/II activities underwent ACLR and completed KFP tests (four single-legged hop (SLH) tests: single hop (SHP), cross-over hop (XHP), triple hop (THP), and 6-meter timed hop (TimHP)) and a PRM (International Knee Documentation Committee 2000 (IKDC2000)) 6m after ACLR. Two years after ACLR, athletes were asked if they had RPLA or not. Binary logistic regression was used to evaluate which combination of SLHs and IKDC2000 scores 6m after ACLR predicted RPLA 2y after ACLR.

Forty-one athletes (68.3%) RPLA 2y after ACLR. All SLHs and IKDC2000 scores were significant individual predictors ($p < 0.01$) of RPLA. SHP and TimHP were the strongest predictors and individually predicted 34.4% and 31.6% respectively of the variance of RPLA 2y after ACLR. When all SLHs and IKDC2000 scores were entered into the regression model, they significantly predicted 54.4% of the variance ($p < 0.001$).

Athletes who demonstrate functional limb symmetry and score higher on PRM 6m after ACLR are more likely to RPLA 2y after ACLR. Athletes who failed to achieve functional limb symmetry and scored lower on PRM at 6m are not likely to RPLA 2y. Athletes who had functional limb asymmetry 6m after ACLR might choose to modify their activities to avoid multidirectional activities.

3 SYSTEMATIC VARIATION OF MATERIAL AND TRIBOLOGICAL PROPERTIES OF CARTILAGE IN THE BOVINE STIFLE JOINT

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Prior pathomechanical joint studies have suggested that ligament and meniscus tears in the knee increase OA risk for logical biological reasons; namely, because changes in joint kinematics cause sliding to occur on functionally unprepared regions that developed in a milder spectrum of stresses. The aim of this study is to test the hypothesis that material properties and functional properties of cartilage vary systematically across the bovine stifle joint.

A custom built microtribometer was used to probe the tribological response to physiologically consistent sliding conditions with sufficiently high spatial resolution ($< 500\mu\text{m}$) to detect spatial variations. Twenty osteochondral plugs were extracted and tested from ten bovine stifle joints against a nominally smooth and rigid 3.2mm diameter stainless steel sphere.

The results support the hypothesis that properties vary systematically across the joint. The femoral condyles were found to be the region with the lowest effective friction coefficient. The functional responses of cartilage were best correlated to the tensile modulus and permeability of the tissue.

The results of this study suggest that the tribological functionality of articular cartilage does vary throughout the bovine stifle joint. Our findings provide evidence as to why altered loading patterns can lead to osteoarthritis and why damage initiation is more common on the tibial plateau than on the femoral condyles. Because the variations are driven by fundamental biological processes, we anticipate similar variations in the human knee, which could explain the OA risk associated with kinematic changes in a joint. These findings will have applications in cartilage transplant procedures, cartilage evaluation, and tissue engineering.

4 VISION BASED RAPID MODELING OF PERSONALIZED REHABILITATION DEVICES

Qiaosong Wang, Jingyi Yu

Orthopedic injuries are frequently caused by athletic activities in daily life. Therefore, rapid prototyping of customized rehabilitation devices are greatly needed to prevent further damages to musculoskeletal structures. In order to achieve this goal, a precise measurement device is required for capturing 3D coordinates of landmark points corresponding to anatomical features of the wounded person. Currently, the capturing step is done by using coordinate measurement machines (CMM). However, these machines are typically bulky, expensive and require a skilled person to operate. We recently developed an image based measurement system for customizing a rehabilitation device for a subject. This system takes images or video streams from mobile devices such as phones or cameras as input, and automatically reconstructs the 3D mesh model of the subject. Coordinates of visual markers indicating anatomical characteristics of the subject are then extracted from the mesh model. Next, the coordinates are rescaled and aligned with a reference model and can be used to generate a customized computer-aided design (CAD) model for the manufacturing process. Our system is cheap, easy to operate, and can be used immediately after an injury. Preliminary results show that our system effectively captures the 3D coordinates with millimeter precision.

5 ASSOCIATION OF JOINT MOMENTS AND CONTACT FORCES WITH EARLY KNEE JOINT OSTEOARTHRITIS AFTER ACL INJURY AND RECONSTRUCTION

Wellsandt E, Gardinier ES, Manal K, Axe MJ, Buchanan TS, Snyder-Mackler L

Knee osteoarthritis (OA) is common following anterior cruciate ligament (ACL) injury. Abnormal joint loading is one key mechanism in the development of OA. This study's purpose was to determine whether knee moments and contact forces after injury were associated with OA 5 years after reconstruction (ACLR).

Seventeen patients (7 F, age 34.7 ± 11.8) undergoing ACLR completed standard motion gait analysis with electromyography (EMG) prior to (baseline) and after 10 pre-operative rehabilitation sessions (post-training), 6 months after ACLR (6 months), and 2 years after ACLR (2 years). Stance kinetic measures of interest included peak knee adduction moment (PKAM) and knee adduction moment impulse (KAMI).

Medial compartment contact forces were derived using an EMG-driven Hill-type musculoskeletal model.

Weight-bearing posterior-anterior 30 degree radiographs were taken 5 years after ACLR, with OA defined as a Kellgren-Lawrence grade ≥ 2 .

Fisher's exact test and independent t-tests tested differences in demographics, pkMC, PKAM, and KAMI between those with and without OA in the medial compartment (OA, nonOA).

Six subjects had involved knee OA, 11 did not. No demographic differences existed.

There were no group differences in pkMC at baseline or post-training. The OA group had significantly lower pkMC at 6 months ($p=.046$, nonOA: 2.90 ± 0.55 BW, OA: 2.10 ± 0.69 BW) but not at 2 years.

Significant kinetic differences occurred only at baseline in PKAM ($p=.043$, nonOA 0.29 ± 0.08 BW, OA: 0.17 ± 0.04 BW) and KAMI ($p=.037$, nonOA 0.087 ± 0.025 BW, OA: 0.049 ± 0.018 BW).

Patients with OA had lower joint contact forces 6 months after ACLR, with loading becoming similar between groups at 2 years. This unloading followed by reloading may be a perfect storm for the development of OA after ACLR.

6 DYNAMIC STABILITY DURING DUAL-TASK TREADMILL WALKING IN HEALTHY ADULTS

Pei-Chun Kao¹, Kelly Seymour¹, Morgan Kamedze², Christopher Higginson², Jill Higginson¹

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Understanding how humans maintain walking stability while performing a cognitive task is key to preventing falls. It has been shown that healthy adults compromised their gait speed and cognitive performance during dual-task walking. However, it is not clear how walking stability is affected while performing different cognitive tasks. Six younger and nine older subjects participated in the study. We recorded kinematic data as subjects waked on a treadmill at their self-selected speed and under four different conditions: walking only, while receiving the Paced Auditory Serial Addition Test, Symbol Digit Modalities Test, and a cellular phone dialing task. We quantified walking stability by computing dynamic margins of stability (MOS), gait variability, and short-term local divergence exponent (LDE) of the trunk motion. For dynamic MOS, we calculated the distances between the "velocity-adjusted" center of mass position and boundaries of base of support. All subjects had significantly larger mean mediolateral MOS but significantly smaller mediolateral MOS variability during all dual-task conditions ($p < 0.01$) compared to walking only. Correspondingly, subjects walked with significantly greater mean step widths ($p < 0.001$) but smaller step width variability ($p < 0.05$) during dual-task walking than walking only. In addition, subjects walked with significantly less variability of ankle and knee joint angles and trunk mediolateral motion during dual-task walking compared to walking only. Moreover, all subjects had similar values of short-term LDE during all conditions, indicating that subjects' local stability was not affected by the dual-task conditions. The current findings suggest that healthy subjects may try to control their foot placement, joint kinematics and trunk motion during walking under dual-task conditions to ensure sufficient margins of stability and to maintain local stability similar to the baseline.

POSTER PRESENTATIONS

Bone, Cell & Cartilage



1 THE EFFECT OF DELAYED LOADING ON IN VITRO MICROFRACTURE MODEL

Miri Park, Monideepa Chartterjee, Anna Gonye, Brandon Zimmerman, Lynn Snyder-Mackler, X. Lucas Lu

Microfracture is an arthroscopic surgery to promote the repair of a cartilage lesion with subchondral bone marrow. However, quality of the repaired tissue in microfracture is often inferior to the surrounding cartilage. Improvement of surgical procedure or rehabilitation protocols requires animal or clinical studies, which could be expensive with ethical limitations. In this study, we proposed to investigate the effect different mechanical loading profiles on the outcome of microfracture surgery using an in vitro culture model.

Cartilage-bone cores were harvested from tibia plateau in knee joints of 3-month-old calves. An artificial cartilage lesion was made in the center of an explant by removing cartilage tissue. Subchondral bone marrow was harvested from the same joint and filled in the lesion. Using this model, we have shown that bone marrow cultured in the lesion of cartilage-bone explants can generate cartilaginous tissue with the supplement of proper medium and growth factors. Two different loading profiles were utilized, one with immediate stimulation from day 1 or a 2-week delayed stimulation each for 6 weeks.

Using this innovative in vitro microfracture cartilage-bone co-culture model, we examined the effects of growth factors and mechanical stimulation. The addition of TGF- β 3 showed a significant increase in the stiffness, biochemical content and chondrogenesis gene expression in repaired cartilage. Mechanical loading of both direct and delayed profiles improved the quality of the newly generated tissue compared to groups with no loading. Delayed mechanical loading was beneficial for new tissue generation from bone marrow.

2 BISPHOSPHONATE RESCUED ARTICULAR CARTILAGE FROM TRAUMA DAMAGE

Miri Park, Yilu Zhou, Liyun Wang, X. Lucas Lu

Zoledronic acid (ZA) is a bisphosphonate drug approved by FDA for osteoporosis treatment. We found that ZA can efficiently suppress the development of post-traumatic osteoarthritis in a Destabilization of medial meniscus mouse model. However, little is known about the chondroprotective mechanisms of ZA. In this study, we hypothesized that ZA can directly regulate the metabolic activities of chondrocytes. The objectives are to prove that ZA treatment can 1) rescue the trauma damage on cartilage allografts and 2) promote the beneficial effects of mechanical loading during in vitro culture of cartilage.

Cartilage allografts from calf knee joints were cultured in serum-supplemented medium for 1 week to simulate trauma damage on cartilage during joint bleeding. The allografts were then cultured with or without 1 μ M ZA for 4 weeks. Mechanical stimulation was applied daily with 10% preload and \pm 3% dynamic loading.

For damaged cartilage with 1-week serum exposure, the Young's modulus of allografts increased more than 200% after 4-week rescuing culture in medium containing ZA, while the non-ZA group showed a 56% increase. In the non-ZA group, 19% of chondrocytes showed spontaneous calcium responses within 15 minutes of imaging, and the value remained constant for 4 weeks.

ZA treatment also significantly improved tissue stiffness of cartilage cultured with mechanical stimulation, as well as the cell viability and spontaneous calcium signaling. Expression levels of type I, II collagen and aggrecan genes were significantly higher in the ZA group.

Treatment with ZA can rescue the mechanical integrity of cartilage after trauma damage induced by serum exposure and promote the beneficial effects of mechanical stimulation during in vitro culture. We showed that the chondro-protective effect of ZA is correlated with the intracellular calcium signaling of chondrocytes.

3 QUANTIFYING DIFFUSION IN POROUS VISCOELASTIC MATERIALS USING CORRELATION SPECTROSCOPY

Janty Shoga & Christopher Price

An early sign of osteoarthritis (OA) is the loss of proteoglycans from the cartilage matrix. Due to the multiphase and viscoelastic nature of cartilage, this loss can alter interstitial fluid flow behavior. Thus, measurement of fluid flow within the tissue could not only inform cartilage biology, but also be diagnostic for OA. The goal of this study was to demonstrate the application of correlation spectroscopy to the study of the equilibrium microfluidic environment of agarose and cartilage through in situ quantification of diffusion. Samples included agarose gels of three different concentrations, and bovine calf cartilage from the medial femoral condyle at different zonal depths.

Samples were cut into cylindrical plugs (1-mm high, 3-mm diameter) and soaked in dilute solutions of various molecular weight fluorescent tracer molecules. Samples were axially loaded, in unconfined compression, to 0, 10, 20, and 30% strain and the diffusivities of the various tracers were determined using fluorescence correlation spectroscopy (FCS).

Increasing solute size, matrix density, and compressive strain resulted in decreased tracer diffusivity in agarose at equilibrium. In cartilage, increasing solute size also resulted in decreased diffusivity. In the superficial cartilage zone, diffusivity decreased with increased strain. In the middle and deep zones no consistent trend, with respect to strain, was observed among diffusivities.

These results demonstrate that FCS can be used to accurately quantify variations in diffusivity in agarose and cartilage. Raster image correlation spectroscopy (RICS) data, acquired simultaneously under the conditions described, is being analyzed to demonstrate effectiveness in the 2-D micro-scale mapping of diffusivity within cartilage. Additionally, ongoing work, building upon these techniques, strives to develop methods of quantifying dynamic, load-induced convective fluid/solute flows within cartilage using advanced spatiotemporal image correlation spectroscopy (STICS) techniques.

4 IS THERE A RELATIONSHIP BETWEEN ADIPOSITY OF THE LOWER LIMB AND TRANSMISSION OF A HIGH-FREQUENCY, LOW-MAGNITUDE VIBRATION ACROSS THE TIBIA AND FEMUR IN CHILDREN WITH SPASTIC CEREBRAL PALSY?

Harshvardhan Singh, Daniel Whitney, Freeman Miller*, Christopher Modlesky

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It is known that there is a greater fat concentration and a lower bone mass in the lower limbs of children with spastic cerebral palsy (CP). Previous studies suggest that a high-frequency, low-magnitude vibration (HLV) provides an osteogenic stimulus to bone in children with CP. It is plausible that vibration transmission is impacted by the concentration of fat in the lower limb. The aim of this study was to determine if the transmission of an HLV signal to the distal tibia and distal femur is negatively related to percent fat of the lower limb in children with spastic CP. 12 children (4-11 years) with CP and a Gross Motor Function Classification between I – III participated in this study. Children stood on an HLV platform (0.3 g at 30 Hz) while vibration transmission was measured at the medial malleolus of the tibia (distal tibia) and the lateral condyle of the femur (distal femur) by two triaxial accelerometers. Dual-energy X-ray absorptiometry was used to determine the percent fat of the lower limb. There was no significant relationship between percent fat of the lower limb and vibration transmission at the distal tibia ($r = 0.092$, $p = 0.776$) or the distal femur ($r = -0.240$, $p = 0.0453$). The findings suggest that the degree of adiposity in the lower limb does not affect transmission of an HLV across the tibia and femur.

5 SPONTANEOUS CALCIUM RESPONSE OF IN SITU CHONDROCYTE AND RELATED PATHWAYS

Yilu Zhou, Jie Ma, Liyun Wang, X. Lucas Lu*

Calcium signaling is one of the earliest responses of chondrocytes under mechanical stimuli, and is the upstream of many cellular activities. However, few studies have identified the signaling pathways regulating the autonomous calcium oscillation inside chondrocytes. In this study, roles of nine signaling pathways in $[Ca^{2+}]_i$ signaling were investigated.

Cartilage allografts from calf knee joints were harvested. Effects of nine pathways in $[Ca^{2+}]_i$ signaling were studied using a corresponding agonist or antagonist. These pathways included extracellular calcium source, intracellular endoplasmic reticulum (ER) calcium store, PLC-IP3 pathway, ATP pathway, gap junction, T-type voltage gated calcium channel (VGCC), TRPV4 channel, and stretch-sensitive channels on plasma membrane. Depletion of extracellular calcium eliminated most of the calcium responses in chondrocytes, indicating that extracellular Ca^{2+} influx is required to initiate the spontaneous $[Ca^{2+}]_i$ oscillation. Blocking the PLC-IP3 pathway or emptying ER calcium store significantly reduced the responsive rate, indicating that the release and refill of ER calcium stores are involved in the spontaneous $[Ca^{2+}]_i$ oscillation. Blocking stretch-sensitive channel, TRPV4 channel, T-type VGCC and purinergic receptors can significantly reduce the spontaneous $[Ca^{2+}]_i$ signaling rate, however, impeding the gap junction has no significant effect. Interestingly, hydrolysis of extracellular ATP has no effect on the spontaneous $[Ca^{2+}]_i$ signaling of in situ chondrocytes.

We identified the roles of nine pathways in the spontaneous calcium oscillations of chondrocytes residing in cartilage tissue. It is clear that the autonomous intracellular calcium response is mainly initiated by influx of extracellular calcium. The spontaneous calcium response also relies significantly on the release of intracellular ER calcium stores. TRPV4 and mechanosensitive channels are also involved in the spontaneous signaling, but gap junctions does not play an essential role.

6 EFFICACY OF BOUNDARY LUBRICANTS ON TMJ DISC AND CONDYLAR CARTILAGE

Brandon K. Zimmerman, David L. Burris, X. Lucas Lu

The TMJ disc glides on the mandibular condyle during daily movement. Injection of intra-articular lubricants is frequently utilized to reduce friction and alleviate pain in TMD, but the biomechanical mechanisms underlying such treatment and its effectiveness in reducing friction remains unclear. Using a novel custom-built microtribometer, we evaluated and compared the effectiveness of synovial fluid (SF), hyaluronic acid (HA), and PBS as exogenous lubricants. Testing was performed in the central region in the anterior-posterior direction under 4 normal compression forces and 4 sliding speeds (25, 50, 100, 200 mN; 500, 1000, 2000, and 3000 μ m/s). During each test, a small amount of either HA, SF, or PBS was added to the central region to serve as a lubricant. We found that 1) Dependence of frictional coefficient on normal force was detected for HA and SF on both condyle and disc; 2) Significant difference between all three lubricants was seen on both tissues, with PBS providing the lowest friction coefficient and HA the highest; 3) No lubricant demonstrated any relationship between frictional coefficient and sliding speed. The results suggest that injection of lubricants may have limited tribological effectiveness for healthy tissue during physiologically relevant migrating contact. The mechanism behind the lubricating ability of HA appears to be metabolic rather than mechanical. It has been proposed that HA protects lubricating phospholipids from lysis by PLA2, indirectly maintaining low friction, and the results of the present study support this, as HA was not seen to be an effective boundary lubricant.

7 IMAGING AND QUANTIFYING MUSCLE-BONE CROSSTALK THROUGH INTACT PERIOSTEUM

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During skeletal growth, strong functional relationships exist between muscle and bone. Recent evidence suggests that soluble factors produced by the muscle could regulate bone cell activity. The periosteum, a fibrous membrane that tightly covers bone's outer surface, lies adjacent to muscle, and contains osteoprogenitor cells crucial for bone modeling, may be a target of these muscle-derived factors. Furthermore, as an interface, the periosteum may act as a molecular sieve, controlling the penetration and transport rates of these factors into the bone tissue. However, few data are available on the permeability of the periosteum. In this study we aimed to image and quantify the permeability of intact periosteum. Confocal xz imaging was first used to identify the periosteum on the mouse tibial mid-shaft. Using the reflected-light imaging, periosteum's dense irregular connective tissue allowed identification of the periosteum, which was further confirmed by staining the bone using Texas red C2-dichlorotriazine, an amine reactive dye. For a 5-month old C57BL/6J mouse the thickness of periosteum was found to be $\sim 60 \mu$ m. After the periosteum was identified, the PBS solution in the imaging chamber was replaced with a well-mixed tracer solution. Three fluorescent tracers (sodium fluorescein, dextran-3k and dextran-10k) were used to mimic a spectrum of muscle-derived factors. A time series of x-z line scan was then collected to track tracer penetration into the periosteum. To obtain the dynamic transport characteristics, the time series were analyzed using MatLab. We found the measured penetration time for the three fluorescent tracers increased with molecular weight and followed a nearly linear relationship, which allowed us to further predict penetration time for the muscle-derived factors.

8 SEMITENDINOSUS TENDON ELASTICITY RECOVERY POST ACL RECONSTRUCTION

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ACL ruptures are a common sports injury and lead to short and long term physical limitations. ACL repairs are performed in order to stabilize the joint and return function to the individual. Though the short term performance deficits are recovered, the potential for long term disability still remains. More than 50% of patients with ACL rupture have signs of osteoarthritis within 10 years of reconstructions and OA has been linked to altered loading patterns within the knee. One of the most common repair techniques is the semitendinosus(ST)-gracilis hamstring autograft, which has been shown to be more effective in reducing OA than other graft techniques, though the mechanisms supporting these outcomes remain unexplained. The ST tendon has been shown to regrow following surgery, which may be the source of the surgeries efficacy in OA reduction. Therefore, it is the purpose of this study to determine whether the shear modulus recovers with the regrowth of the tendon. Shear wave elastography (SWE) is a non-invasive technique to determine the mechanical properties of soft tissue using an external vibration and a high frame rate ultrasound. Using SWE, the shear modulus of the ST tendons of 3 subjects who have had a ST autograft reconstruction was estimated and compared to the contralateral side. A t-test ($\alpha=0.05$) was used to establish significance. An average difference of 84.8kPa (45% difference; $p=0.166$) was found between the uninvolved and involved tendons. There was not a significant difference between the two values, suggesting that there is a recovery of the mechanical properties of the tendon as it heals.

9 MECHANICAL FUNCTIONS OF SUPERFICIAL ZONE IN TMJ CONDYLAR CARTILAGE

Leonardo Ruggiero, Kelsey Devlin, Brandon Zimmerman, X. Lucas Lu

Mandibular condylar cartilage (MCC) in temporomandibular joint (TMJ) is characterized by a unique superficial zone which is composed of highly aligned type I collagen bundles with little proteoglycan content. The middle- and deep-zone cartilage covered by this fibrous layer exhibits a similar structure with hyaline cartilage in other diarthrodial joints (Fig 1A). The effects of the unique superficial fibrous zone in the daily functions of MCC, such as load bearing and lubrication, are barely known. In this study, we propose to: 1) determine the biomechanical properties, including permeability and tensile and compressive moduli, of both fibrous and middle-deep zones in MCC, and 2) build a 3D finite element (FE) model based on mixture theory to simulate the nonlinear inhomogeneous structure of MCC and determine the biomechanical effects of the superficial zone in MCC daily functions.

10 IN VIVO RESPONSE OF TYPE 1 DIABETIC BONE TO MECHANICAL LOADING DEPENDS ON GENDER AND/OR DISEASE SEVERITY

Ashu Parajuli¹, Xiaoyu Dave Gu¹, Xiaohan Lai¹, Hong Zhang², Mia Mia Thi³, Christopher Price¹, Liyun Wang¹

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Diabetic patients showed increased risk of fracture and bone loss [1], compromised bone structure [2], increased cortical porosity [3], inferior mechanical properties [4]. Non-pharmacological intervention such as mechanical stimulation could be used as an alternative treatment. The objective of the study was to examine bone structural and histomorphometrical changes in diabetic and normal mice after ulna loading.

The right ulnae of 29-week old male and female heterozygous C57BL/6-Ins2Akita (Akita) and wild type C57BL/6J (WT) mice (Jackson Laboratory; n=5-7 mice/group) were subjected to cyclic axial loading to induce ~3500 microstrain on the lateral mid-shaft surface. The mice received calcein labels on Day 4 and Day 15 and sacrificed on Day 18 since the beginning of the loading. Both loaded and contralateral non-loaded ulnae were harvested for structural and dynamic histomorphometry analysis.

Females: Akita female mice showed no significant difference in body weight, but an elevated fasting blood glucose level compared with those of WT females. After mechanical loading, WT females demonstrated robust bone formation and so did Akita females.

Males: Akita males, however, showed more severe side effects of diabetes with a decrease in body weight. As expected, WT males showed robust bone formation after loading. In contrast, Akita males did not show anabolic responses in most of the histomorphometry indices.

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POSTER PRESENTATIONS

Gait

11 FUNCTIONAL PROGRESSION AND RETURN TO ACTIVITY AFTER ACLR IN SOCCER AND NON-SOCCER ATHLETES

Amelia Arundale, PT, DPT, SCS, and Lynn Snyder-Mackler PT, ATC, SCS, ScD

Soccer places unique demands on an athlete's lower extremities as it requires moving the ball while simultaneously supporting the body. Soccer also has a high incidence of anterior cruciate ligament (ACL) injury. These factors could cause the trajectory of recovery after ACL reconstruction (ACLR) for soccer athletes to be different from other athletes. Thus, the purpose of this study was to determine if soccer players are unique in their functional progression through the first year after ACLR.

234 athletes were followed for one year after unilateral ACL tear. Demographic information and function measures were collected after ACL injury and re-evaluated at 6 and 12 months after surgery; as well as return to pre-injury activity level (RTA). Chi-squared and repeated measure two-way ANOVA were used to analyze the difference between soccer and non-soccer athletes.

There were significant differences in RTA at 6 and 12 months ($p=0.006$ and 0.05 respectively). There was a significant time x group interaction ($p=0.032$) for the IKDC2000 with soccer athletes having a smaller change in score over the three time points. There were no interactions or main effects for the single leg hop tests, however there were main effects for group and time for the KOS-ADLS (group $p=0.004$, time $p=0.0001$) and GRS (group $p=0.003$, time $p=0.0001$).

These results indicate that soccer athletes perceive their knee function to be lower than non-soccer athletes. Such lower perceived level of function may be reflected in the smaller number who returned to pre-injury activity level at 6 and 12 months. A further implication is that the single legged hop tests may have a ceiling effect in soccer players.

12 TRENDS IN PEAK LOWER EXTREMITY JOINT POWERS DUE TO CHANGES IN WALKING SPEED AND BODY WEIGHT SUPPORT

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The purpose of this study was to characterize changes in lower extremity peak joint powers across a range of body weight support (BWS) levels and walking velocities in a normal population. We hypothesized that powers would follow the same general trends as joint moments. Previous research from SR Goldberg and SJ Stanhope, 2013 found that ankle and hip peak joint moments linearly decreased with slower walking velocities and with greater BWS, while knee moments did not decrease linearly with slower walking velocities and were insensitive to BWS. Eight adult subjects walked at three walking velocities (0.4, 0.6, and 0.8 statures/s) on an instrumented treadmill, each with three BWS conditions (0%, 20%, and 40% of body weight supported). Six degree of freedom joint powers were calculated using methods from FL Buczek, et al., 1994. Differences in peak joint powers were determined using a multiple regressions model ($p \leq 0.05$). In general, peak joint powers did not follow the same trends as joint moments. While looking at the effect of BWS at a certain walking velocity, peak powers did not significantly decrease with greater BWS except at 0.8 statures/s for both the ankle and hip, nor at 0.6 statures/s for the hip. However, as observed with peak joint moments, peak knee powers did not significantly differ between BWS levels within a walking velocity. All three peak joint powers were significantly less at 0.4 statures/s compared to at 0.8 statures/s. Future studies may find comparing trends in net joint work to be useful in further understanding the differences in peak joint moment and power patterns on the mechanics of gait.

13 FUNCTIONAL STATUS AND RETURN TO SPORT RATES FOR POTENTIAL COPERS AND NON-COPERS 2 YEARS AFTER ACLR

Mat Failla, David Logerstedt, Lynn Snyder-Mackler

Classification of potential copers and non-copers after ACL injury has long been established. Potential copers and non-copers show no difference in function 1 year after surgical reconstruction. The purpose of this study is to examine the functional status of potential copers and non-copers 2 years after ACL reconstruction.

Fifty nine subjects after unilateral ACL rupture. Subjects were screened to determine potential coper or non-coper status. All subjects underwent ACL reconstruction, and returned for testing 2 years after surgery. Data collected included isometric quadriceps strength index (QI), 4 single-legged hop symmetry indexes, Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADLS), Global Rating Scale (GRS), International Knee Documentation Committee 2000 (IKDC 2000), Tampa Scale for Kinesiophobia (TSK-11), and the Marx Activity Rating Scale (Marx). T-tests and chi-square were used for statistical analysis.

No differences were seen between groups in QI ($p=.662$), KOS-ADLS ($p=.911$), GRS ($p=.719$), IKDC2000 ($p=.317$), TSK-11 ($p=.091$), or Marx ($p=.090$). All non-copers returned to sport, and 97% of potential copers returned ($p=.058$). 29% of potential copers did not return to their pre-injury sport level while 28% of non-copers did not return to pre-injury level ($p=.086$). Potential copers were significantly more symmetrical than non-copers during the single hop ($p=.005$) and triple hop ($p=.046$), but not crossover hop ($p=.236$) or timed hop ($p=.136$).

There were no differences in return to sport or level, or functional differences between potential copers and non-copers 2 years after ACL reconstruction. While single hop and triple hop were statistically different, both group symmetry indices were above 95%, and therefore are likely not clinically important. Potential coper or non-coper classification after ACL injury does not affect outcomes 2 years after ACL reconstruction.

14 PRE-OPERATIVE PREDICTORS OF CONTRALATERAL TKA FOLLOWING UNILATERAL TOTAL KNEE ARTHROPLASTY (TKA)

Portia Flowers, Joseph Zeni, Jr., Lynn Snyder-Mackler

To identify predictors of future contralateral TKA in persons who underwent unilateral TKA at baseline. We hypothesize that bilateral impairments and joint biomechanics will be predictors of contralateral TKA. Seventy-seven subjects who underwent unilateral TKA were evaluated and grouped according to contralateral TKA status (YES or NO). Initial testing was performed 6mos, 1yr, or 2yrs after TKA with at least a 2.5 year follow-up to determine incidence of contralateral TKA. Patient-reported outcomes of knee function and pain, quadriceps strength, active knee extension range of motion, knee flexion moment at peak knee flexion, and peak knee adduction moment (PKAM) were assessed and analyzed bilaterally. Hierarchical logistical regression models were used to determine predictors of contralateral TKA. Limb-by-group differences were determined using 2x2 ANOVA. Descriptive comparisons were made to historic pre-operative and healthy individuals. There were significant main effects of group and limb, with the YES group having bilateral weakness. There were no significant predictors of contralateral TKA for either limb. However, the addition of operated limb strength to the model improved the significance of the model and was nearly a significant addition to the model. With the YES group being weaker than the NO, pre-operative, and healthy groups, these results suggest that quadriceps weakness may play a role in discriminating contralateral limb OA progression. Future work should evaluate rehabilitation protocols that not only restore operated limb strength to pre-operative levels, but exceed it. Although PKAM is predictive of OA progression, current results did find it to be predictive of contralateral TKA. However, previous literature suggests that non-normalized PKAM may be a more clinically relevant measure when analyzing knee OA progression. Therefore, future analyses of incidence of contralateral TKA may include non-normalized PKAM.

15 CAN FREE MOMENT BE USED TO EFFECTIVELY CHALLENGE SUBJECTS' ROTATIONAL LOADING AT THE KNEE?

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Impairment of the anterior cruciate ligament (ACL) is a common injury leading to significant financial burdens. While tibial translation is most commonly indicated as an injury mechanism tibial rotation also contributes and can lead to rotational instability. Understanding mechanisms and consequences of rotational instability can inform therapists in designing rehabilitation. ACL tears typically occur when landing and/or changing directions and so the run cut and pivot landing tasks are typically used as research tools. Studies exploring kinetics of the knee during running and cutting maneuvers found significant external rotation moments generated during sidestepping tasks [Besier et al. 2001]. It is difficult to directly evaluate ACL-deficient patients in internal and external rotations using certain pivot landing tasks due to risk of further injury. In an effort to actively test subjects in internal and external rotational loading without risking injury our lab developed a task to use the free moment as an indicator of 'rotational challenge'. Subjects stood barefoot approximately hip-width apart on two force plates, a separate force plate for each foot. Subjects, 5 healthy males with no history of ACL injury, generated 10, 50, and 80% of their maximum free moment in both the internal rotation (IR) and external rotation (ER) directions. Kinematics and kinetics of the lower limbs were recorded throughout the data collection. We found that as the free moment effort increased the rotation angle of the hip also increased. Additionally, transverse knee moments increased as free moment effort increased. We found increased transverse knee moments during the ER versus the IR condition. Our results indicate we are able to challenge patients in rotational loading using the free moment measure.

16 KINETIC AND KINEMATIC CHANGES IN GAIT DUE TO DUAL-TASKING

Kelly Seymour¹, Morgan Kamerdze², Christopher Higginson, Ph.D², Jill Higginson, Ph.D¹

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Although historically considered an automatic process, gait control has been shown to consume attentional demands. Identifying the impact of cognitive tasks on motor tasks could detect increased fall risk and lead to prevention strategies. The impact on kinetics, kinematics, and spatial parameters due to dual-tasking is currently unknown. The objective of this study is to identify how dual-tasking impacts motor task performance in healthy older adults compared to younger adults.

Participants completed a neuropsychological assessment consisting of various cognitive tests to define a baseline measure of cognitive abilities. Three tasks were then repeated during treadmill walking: a working memory task (Paced Auditory Serial Addition Test, PASAT), a processing speed task with components of visual attention (Symbol Digit Modalities Test, SDMT), and a visual attention and fine motor skills task (cellular phone dialing task, Phone). Three walking conditions were used for dual-tasking: self-selected, fast (120% of self-selected), and limp speeds (induced by the split-belt treadmill with one belt moving at self-selected and fast speed).

Changes in stride length and width means and standard deviations as well as peaks and variances of lower extremity kinematics between younger and older adults indicate that all types of dual-tasking have an impact on gait. Changes in gait performance with the addition of a cognitive task show that gait is not fully automatic. Furthermore, dual-tasks may increase fall risk in older adults because some gait changes such as stride width variability, and peaks and range of motion for knee flexion, hip extension, and ankle plantarflexion are often indicative of a fall. Future implications include developing prevention strategies for older adults at risk of falls.

17 THE RELATIONSHIP BETWEEN FEAR AND FUNCTION IN THE ACL DEFICIENT KNEE

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The Tampa Scale for Kinesiophobia (TSK-11) is a valid and reliable measure of fear of movement and re-injury in the ACL deficient population. Previous research has found the TSK-11 to be related to self-reported function and ability to return to sport. The purpose of this study is to evaluate whether a significant change in TSK-11 score, after a neuromuscular training program, correlates with functional performance and self-reported function in ACL deficient subjects.

Eighty Level I/II subjects after isolated ACL rupture were included in this analysis. All patients performed quadriceps strength testing (QI), single-legged hop testing (single hop, cross-over hop, triple hop, and 6-m timed hop), a global rating scale (GRS) measure, TSK-11, and the International Knee Documentation Committee Subjective Knee Form (IKDC) before and after a neuromuscular training program. The change scores from pre training to post training were calculated for all the aforementioned tests. Correlations were performed between change score in TSK-11 and change scores in all other measures. SPSS 21 was utilized to run bivariate correlations. P-value was set at $p < .05$.

Significant correlations were found between change score in TSK score and change score in GRS ($r = -.298$; $p = .008$), IKDC ($r = -.425$; $p < .001$), single hop ($r = -.360$; $p = .003$), cross over hop ($r = -.308$; $p = .013$), triple hop ($r = -.335$; $p = .006$), and timed hop ($r = -.273$; $p = .048$). No correlation was found between change in TSK score and QI ($r = .013$; $p = .913$).

Small correlations were found between the change in TSK and all hop tests and self-reported measures. A subject's change in TSK score is minimally related to a change in other self-reported or functional measures.

18 PHYSICAL THERAPY TREATMENT IMPROVES PATIENT PERCEIVED KNEE FUNCTION AFTER ACL INJURY

Kevin Lapham, Kathleen White, Lynn Snyder-Mackler

Every year, 250,000 ACL injuries occur, and of those, 175,000 undergo reconstruction. After surgery, risk for re-injury and development of knee osteoarthritis is increased. Many believe poor patient perceived knee function and gait asymmetries contribute to these poor outcomes. The purpose of this research is to compare two pre-operative physical therapy treatments and their effect on patient perceived knee function and gait biomechanics acutely after ACL injury.

Fifty-one subjects with an isolated, unilateral ACL injury, who participated in jumping, cutting and pivoting activities ≥ 50 hrs/yr prior to their injury, were included in this study. Subjects received one of two treatments; progressive strengthening or progressive strengthening augmented with perturbation training. Vertical ground reaction force was used to evaluate limb symmetry before and after training with a limb symmetry value as the involved limb minus the uninvolved limb. Patient perceived knee function measures included the global rating score (GRS) of perceived knee function and the International Knee Documentation Committee (IKDC 2000) subjective knee form. Analysis of variance and t-tests were used to determine limb symmetry and patient perceived knee function. Significance was set $p \leq 0.05$.

All subjects had a significant improvement in perceived knee function after training (GRS: Pre-training (mean 63.84%, SD 18.76), Post-training (74.80%, 13.23) $p < 0.001$; IKDC: Pre-training (59.64%, 12.45), Post-training (68.44%, 10.85) $p < 0.001$). Conversely, there was no change in limb symmetry over time between the two treatment groups ($p = 0.84$) with greater force on the uninvolved limb.

Regardless of treatment, patient perceived knee function improved. However, there was no significant improvement in vertical ground reaction force symmetry.

A progressive treatment after ACL injury improved patient perceived knee function; however, gait asymmetries persisted. Future research is needed to investigate additional contributors of these asymmetries.

POSTER PRESENTATIONS

Methods &
Modeling**19** A HYBRID EMG-DRIVEN
COMPUTED MUSCLE CONTROL
METHOD TO ESTIMATE HIP MUSCLE
FUNCTION IN HEALTHY CONTROLS*John Ramsay, Thomas Buchanan, Jill Higginson*

Computed muscle control (CMC) is a powerful method for estimating muscle forces during complex dynamic tasks. One of the major benefits of CMC is the ability to estimate forces for a high number of muscles. To solve the muscle redundancy problem, the algorithm uses a proportional-derivative controller to estimate muscle activations that satisfy the current kinematic state of the musculoskeletal model. At each time step, the muscle forces are optimized by minimizing the sum of the activations squared for all muscles in the model. However, CMC has been shown to over predict muscle activations and forces in subjects with impaired activations or changes in muscle properties, such as stroke. To address this limitation, we have developed a hybrid method that uses an existing EMG-driven model to estimate subject-specific muscle properties and muscle activations from surface EMG of a subset of muscles and uses CMC to predict the remaining muscle activations and forces. The purpose of this study was to evaluate the difference in estimated hip muscle function between the default CMC method and the hybrid method in healthy controls during swing. Kinematic, kinetic, and EMG data from two healthy subjects walking at their self-selected speeds were used as input into both simulations. Muscle function was defined by individual muscle moment for hip flexion/extension and abduction/adduction. We found that for both methods, while the predicted role of each muscle was the same, the default CMC method had lower muscle moment magnitudes. By including the known neural command and estimated muscle properties from the EMG-driven model, tuned simulations of pathological gait may produce more realistic measures of muscle function.

20 PRELIMINARY ASSESSMENT
OF A NEW MUSCULOSKELETAL
MODEL OF THE SHOULDER AND UPPER
EXTREMITY*R. Tyler Richardson, Robert G. Quinton, Kristen F. Nicholson,
and James G. Richards*

Musculoskeletal modeling possesses the capability to estimate internal muscle forces that cannot be directly measured. However, the validity of the results must first be assessed to ensure that the model is sufficiently robust to recreate the mechanics that occur in vivo. In an effort to overcome significant limitations of previous upper extremity models, a new shoulder model (UDSM) has been developed for preliminary evaluation. Following adequate assessment, this new model will ultimately be used to estimate muscle forces and activation patterns that characterize an individual patient's muscular deficits, and to provide clinicians with previously unavailable patient-specific data to inform clinical and surgical interventions. A motion capture system recorded the kinematics of the trunk and upper extremity segments during shoulder abduction for one healthy subject. Muscle forces were computed using the static optimization tool. The model estimations of muscle forces were evaluated qualitatively by comparing the timings and relative magnitudes with the expected anatomical actions of each muscle. The deltoid produced the largest forces followed by the trapezius and serratus anterior which both generated moderate forces. The supraspinatus and infraspinatus produced small to moderate levels of force in the middle and end of the trial respectively. All other muscles were minimally active. The results of this initial evaluation demonstrate that the relative magnitudes and timings of the muscle forces estimated by the UDSM for shoulder abduction qualitatively agree with the expected anatomical actions. These promising preliminary results indicate that future studies are warranted to provide further validation for the UDSM.

POSTER PRESENTATIONS

Motor Control

21 KNEE STIFFNESS REGULATION CHANGES WHEN STARTLED AT DIFFERENT TIMES

An YW, Swanik CB, Walls BL

Altered neuromuscular control (NMC) contributes to the high incidence of non-contact joint injury mechanisms. Recent studies have shown that unexpected, starting events alter preparatory (feed-forward) and reactive (feedback) systems needed for maintaining knee stability. However, it remains unclear how the timing of starting episodes may interrupt joint stiffness regulation strategies necessary for functional stability. Sixty-six males and females with no history of knee injury participated in either Short Startle Delay (SSD, 36 subjects) or Long Startle Delay (LSD, 30 subjects) for testing joint stiffness and muscle activity (Quadriceps, Hamstrings) on a custom-built device. Subjects were instructed to relax and immediately provide maximum resistance to a perturbation from 30-degree to 70-degree flexion. Perturbations were randomly applied in 2 different conditions: control and acoustic startle (100dB, 50ms duration, 100ms). The time of startle was 100ms for the SSD group and 1000ms for the LSD group. Short-range (0-4°) and the total-range (0-40°) normalized knee joint stiffness (Nm/°/kg) was compared across groups (2-levels) and conditions (2-levels) by using 2-way repeated-measures ANOVAs. Muscle activity (timing and amplitude) was compared across groups (2-levels), conditions (2-levels), and muscles (4-levels) by using 3-way repeated-measures ANOVAs. The results revealed the acoustic startle condition produced higher short-range stiffness than the control condition. LSD group showed greater total-range stiffness than SSD group under the acoustic startle condition. LSD group also had higher peak EMG activity, 150ms before and 250ms after-perturbation in both the quadriceps and hamstrings. Our results may suggest that the timing of startling events may interrupt NMC and stiffness regulation strategies and that startling events preceding a knee load by 100 ms may be more adverse to knee stability than those occurring 1 second before a perturbation.

22 NEUROMUSCULAR IMPROVEMENTS FOLLOWING A SPEED-BASED CYCLING INTERVENTION

Maria Bellumori, MS & Christopher A. Knight, PhD

Although slow movement is obvious among older adults, little research supports the safe practice of speed-based exercise in this population. The purpose was to determine the neuromuscular effects of a 6-week speed-based exercise program in older adults. Stationary recumbent cycling was selected to minimize fall risk. Minimal resistance reduced musculoskeletal loads and cardiovascular demand. Two weekly 30-min exercise sessions consisted of interval training in which subjects pedaled at preferred cadence and with 10, 20-s fast cadence intervals. Participants (n=14, 73(7.6) years) completed pre- and post-exercise tests, and a 4 week retention test. No significant changes were observed in a subset of participants (n=7) who served as time-controls. After training, there were improvements in rates of force development (RFD), time to peak force (TTPF), and surface electromyography rate of rise (RER) during rapid isometric knee extension. Improvements were maintained 4 weeks after the intervention. A central mechanism was implicated because the lower extremity exercise elicited improvements in the untrained upper extremities (isometric elbow extension RFD, TTPF, and RER, p<.05). These results support a speed-work strategy which complements current exercise recommendations for older adults and potentially people with movement limitations while supporting the literature related to neural adaptations to high-speed training in older adults.

23 THE TRADE-OFF BETWEEN HIP FLEXORS AND ANKLE PLANTAR FLEXORS DUE TO AGE AND SPEED

Amy Bucha and Jill Higginson

Muscle torque shows a decline with age, evident in both men and women. The hip flexors and ankle plantar flexors propel the body forward, therefore a decrease in ankle plantar flexor torque is consistent with a decrease in gait speed of elderly subjects seen by Winter. In previous studies a trade-off was found between hip flexor muscles and ankle plantar flexor muscles, suggesting that the hip muscles form an adaptation to make up for the decreased torque production in plantar flexor muscles during aging. The purpose of this study was to determine whether a relationship exists between the hip flexor and ankle plantar flexor muscle forces for (1) older and younger subjects and (2) self-selected and fast walking speeds.

Motion capture data was analyzed for healthy young and older adult subjects. Models were created in Visual3D for each subject and simulations were created in OpenSim to compute muscle forces in the ankle plantar flexors and hip flexors from contralateral heel strike to toe off.

The preliminary data shows that, while walking with an increase in speed, younger subjects show a decreased hip/ankle ratio, while older adults show an increased hip/ankle ratio, implying that the younger adults are relying more on their ankle plantar flexors with an increased speed while the older adults rely more on their hip flexors.

A better understanding of the different trade-off between ankle plantar flexors and hip flexors for older and younger adults can be used to design a rehabilitation technique for older adults whose instability is derived from plantar flexor weakness.

24 EFFECTS OF ARM PROXIMAL AND DISTAL MUSCLES FATIGUE ON FORCE COORDINATION IN MANIPULATION TASKS

Nicholas Emge¹ Mehmet Uygur¹ Mandic Radivoj^{1,2} Thomas Kaminski^{1,3} Todd Royer^{1,3} & Slobodan Jaric^{1,3}

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Effects of muscle fatigue on force coordination and task performance of various manipulation tasks are explored. Grip force (GF; normal force component acting at the digits-object contact area) and load force (LF; tangential component that lifts and holds objects) were recorded prior to and after fatiguing the distal (DAM; i.e., GF producing) and proximal arm muscles (PAM; LF producing). Results reveal a deterioration of GF scaling (i.e., averaged GF/LF ratio), GF-LF coupling (their correlation), and task performance (ability to exert a prescribed LF pattern) associated with DAM, but not PAM fatigue. Deteriorated force coordination clearly increases the likelihood of dropping an object, however, the observed selective effects of DAM and PAM fatigue represent a novel finding deserving of further research.

25 TITLE: THE SHORT TERM EFFECT OF EXERGAMING ON PHYSICAL ACTIVITY LEVELS AND EXECUTIVE FUNCTION IN CHILDREN WITH AND WITHOUT AUTISM SPECTRUM DISORDER: PRELIMINARY RESULTS.

Daphne Golden, MPT, DPT, Danielle Brumbley and Nancy Getchell, Ph.D

The purpose of this research is to investigate the effect of exergaming on physical activity (PA) level achieved, executive function and perceived enjoyment in boys with and without Autism Spectrum Disorder (ASD). Method: Repeated measure design with 2 groups and 3 physical activities. Participants: 15 boys (8-11 years) with ASD and 15 age and BMI matched neurotypicals. Equipment: Actical Accelerometer for testing of physical activity level, Inquisit Computer Children's Flanker Task of executive function, and 3 point Scale of Enjoyment. Gaming unit is an Xbox 360 for the sedentary videogame with a Kinect unit for the exergame. Physical activity level measures are physical activity count (AC) and percent time in moderate to vigorous physical activity (MVPA). Executive Function measures are number correct, and the response time on the Flanker. Enjoyment measure is enjoyment level. Protocol: Day 1 inclusion testing. Day 2 the executive function and physical activity level pretest data are collected. Days 3-5 are randomly assigned condition. Testing includes a period of 5 minutes rest. Then physical activity is performed for 20 minutes. Followed by a 10 minute rest period. Enjoyment level measured after physical activity and then executive function post condition data is collected. Statistical Analysis: A repeated measure MANOVA will be used between group and condition. Currently, 6 ASD and 2 typical boys have met inclusion criteria and results will be reported from these participants.

POSTER PRESENTATIONS

Osteoarthritis

26 TISSUE, CELLULAR, AND MOLECULAR EFFECTS IN EARLY POST-TRAUMATIC OSTEOARTHRITIS; IMPLICATIONS FOR PHARMACOLOGICAL TREATMENT

Michael David, BS, and Christopher Price, PhD

Biomedical Engineering

Post-traumatic osteoarthritis (PTOA), an accelerated form of osteoarthritis (OA), is an insidious disease of progressive diarthrodial joint articular cartilage degeneration that results directly from traumatic joint injury, e.g., meniscus or ligament tears, and is common in athletes and military service members. Approximately 50% of those who experience a ligament tear develop OA within 15 years. Unlike other causes of idiopathic OA, such as chronic joint loading or ageing, with PTOA the initial timing of the disease is known. Interestingly, previous work at UD using systemic administration of Zoledronic Acid (ZA), a FDA-approved bisphosphonate used to treat bone loss, demonstrated histologically the long-term prevention of cartilage damage and PTOA. However, in that study, and many like it, the early cellular and molecular mechanisms involved in PTOA-related cartilage damage and drug-mediated protection remain unknown. We hypothesize that immediately following injury changes in chondrocyte metabolism and fate determination precipitate the vicious cycle of cartilage degeneration in PTOA. By targeting these early changes pharmacologically with intra-articular injection (i.a.) of ZA, the development of PTOA can be prevented or hindered. To address this hypothesis, a murine joint instability injury model of PTOA (destabilization of the medial meniscus) is being utilized to study the early structural, compositional, cellular, and molecular changes associated with trauma-induced PTOA. In this study we will present histological and immunohistochemical analyses of non-treated, control and injured knees across a wide range of post-surgical time points at 3-, 7-, 14-, 56- 84- and 112-days post-injury. Ultimately, this study will identify early mechanisms in injury-related cartilage degeneration and determine the efficacy of targeted drug delivery systems, such as i.a. ZA, to prevent the onset of PTOA.

27 THE USE OF A WII BALANCE BOARD AS A RESEARCH AND REHABILITATION TOOL

Gregory Gillispie, Sumayah Abujaber PT, MS, Joseph Zeni PhD, PT

Osteoarthritis treatment often involves surgery and extensive rehabilitation. Even after pain and strength levels are returned to normal, patients still exhibit movement asymmetries which increase the load on the nonoperated limb. Movement asymmetry is negatively correlated with functional performance and restoring symmetry should be a rehabilitation goal. Force Plates are the current gold standard for measuring GRF asymmetries in research, but are expensive and not conveniently portable making them unrealistic to implement in physical therapy clinics and impossible to use for in-home treatment. We hypothesized that a Wii Balance Board would be an effective tool for collecting GRF when compared to force plates.

Subjects were patients with unilateral knee or hip osteoarthritis who were scheduled for, or have received within the last year, a total joint arthroplasty. Currently 17 subjects have undergone testing. Subjects were asked to perform six sit-to-stand movements, half on the Wii Balance Board and half on a pair of Bertec Force Plates. Vertical GRFs were measured for each limb and used to calculate the Peak Stand, Peak Sit, and Symmetry Index values. The average BB Peak Stand values were 457N (affected limb) and 504N (unaffected limb) compared to 433N and 519N respectively for the FP. The average BB Peak Sit values were 445N (affected limb) and 475N (unaffected limb) compared to 416N and 486N respectively for the FP. The Pearson Correlation Coefficients between the BB and FP for the Symmetry Index were 0.92 for the standing portion and 0.88 for the sitting portion of the task. The data presents considerable evidence that the Wii Balance Board can be used to measure movement asymmetry in a clinical population.

28 STRATEGIES TO IDENTIFY NOVEL
BONE BIOMARKERS FOR EARLY
DETECTION OF OSTEOARTHRITIS

*Padma P Srinivasan, Angela R. Stegmuller, Randall L Duncan,
Catherine Kirn Safran.*

Biological Sciences

Subchondral bone sclerosis in joints is associated with late stage osteoarthritis (OA). Recent studies showed that during the early development of the disease soluble metabolites released from mechanically stressed subchondral osteoblasts are responsible for induction of cartilage degeneration. The goal of this project is to identify novel bone biomarkers for early detection of OA. We subjected the MC3T3-E1 pre-osteoblastic cells to Fluid Shear Stress (FSS ~ 3.5 dynes/cm²) for 2 hours. A significant increase in the cyclooxygenase (COX2) and osteopontin (SPP1) mRNA levels were observed in cells subjected to FSS relative to static cells. In addition, western blot analysis showed upregulation of COX2 protein levels. To test the effect of factors released by FSS osteoblasts on cartilage cells, we used conditioned media (CM) from the FSS osteoblasts to treat primary mouse sternal chondrocytes cultured in micromasses. Gene expression profiling of micromasses cultured in the presence of FSS osteoblast CM for one week, showed a significant increase in the mRNA levels of collagen X, alkaline phosphatase and MMP13 relative to control micromasses. In contrast, no significant changes were observed for cartilage matrix proteins such as aggrecan and collagen II. This data supports the idea that the CM from the FSS osteoblasts contains metabolites capable of activating catabolic pathways in chondrocytes. To identify these factors, our current approach is to isotopically label static and sheared osteoblasts with either carbon-12 or carbon-13, respectively; and assess their intracellular and extracellular metabolic profiles using a mass spectrometry-based Isotopic Ratio Outlier Analysis (IROA). Ultimately, this work will help develop effective diagnostic tools and therapeutics aimed at lessening progression of OA.

POSTER PRESENTATIONS

Stroke & Brain



29 THE BASELINE ACTIVITY IN THE PREFRONTAL CORTEX IN HEALTHY PARTICIPANTS. THE EFFECTS OF EYES CONDITION.

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The prefrontal cortex (PFC) plays an important role in cognitive process related to executive functions. It activates not only when individuals perform executive function-related tasks but also in resting states. Brain activity during resting states provides a baseline for interpreting task-induced brain activities. Both eyes open and eyes closed condition are commonly used baseline conditions. However, brain activity in eyes open condition is different from activity in eyes closed condition. The aim of this study was to examine differences in brain activity between eyes open and eyes closed conditions during resting states to provide a rationale of proper selection of baseline condition. Total of 36 participants in 3 age groups were recruited in this study including twenty-four adults, 5 12-15 years old children, and 7 8-11 years old children. Concentrations of oxygenated hemoglobin (oxy-Hb) and deoxygenated hemoglobin (deoxy-Hb) were obtained using functional near-infrared spectroscopy (fNIRS) in eyes closed and eyes open conditions, 3 minutes each. Contrasts were tested to compare the differences of concentrations of oxy-Hb and deoxy-Hb between eyes open and eyes closed conditions. A significant higher concentration of oxy-Hb was found in eyes closed condition indicated a higher activity in the PFC in eyes closed condition during resting state. Therefore, eyes open condition may be a better choice for baseline condition since it has less activity in the PFC that could interfere with interpretation of task-induced activity.

30 A STRENGTH ENHANCEMENT PARADIGM FOR PRESCRIPTION OF PASSIVE-DYNAMIC ANKLE-FOOT ORTHOSES FOR INDIVIDUALS POST-STROKE

Elisa S Arch, Darcy S Reisman, Steven J Stanhope;

In healthy gait, the plantar flexors act eccentrically to provide dorsiflexion resistance during the second rocker of the stance phase of gait. Passive-dynamic ankle-foot orthosis (PD-AFO) bending stiffness is believed to be able to replace lost plantar flexor function. We previously developed and demonstrated feasibility of a strength substitution paradigm, in which PD-AFO bending stiffness substituted for a prescribed percentage of a healthy individual's peak plantar flexion moment. Thus, for individuals with plantar flexor weakness we hypothesized a strength enhancement paradigm, in which PD-AFO bending stiffness is prescribed to account for the plantar flexion moment deficit, would be effective. The purpose of this pilot study was to evaluate the strength enhancement paradigm for individuals post-stroke with plantar flexor weakness. First, baseline kinetic and kinematic movement analysis data were collected as subjects post-stroke (n=2) walked on a split-belt instrumented treadmill at their self-selected velocity without any AFO, if possible. Scaled paretic ankle joint moments were compared to scaled, velocity-matched ankle joint moments from our normative database, and percent differences in peak plantar flexion moments were calculated. Customized PD-AFO bending stiffness was prescribed as the difference in peak plantar flexion moments divided by the average normal ankle excursion during the second rocker of stance. Subjects then walked while wearing the stiffness-customized PD-AFOs. Results supported feasibility of the strength enhancement paradigm, with the percent difference in peak moments decreasing from the baseline to PD-AFO conditions (Subject A: 25.5% to -3.7%; Subject B: 31.1% to 14.9%). Additionally, step length ratio became more symmetrical (Subject A: 0.78 to 0.92; Subject B: 0.91 to 1.00). Overall gait function may improve even more with training or long-term use of the customized PD-AFOs.

31 THE RELATIONSHIP BETWEEN THE SPATIOTEMPORAL GAIT ASYMMETRIES AND WALKING ACTIVITY IN INDIVIDUALS POST STROKE.

Menki Chen, Kelly Danks¹, Tamara Wright¹, Margie Roos¹, Evan Matthews², William Farquhar², Darcy Reisman^{1,2}

¹Department of Physical Therapy

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Introduction: Daily walking activity in individuals post stroke is very low, well below that of sedentary adults (<5,000 steps/day). Spatiotemporal irregularities in gait are caused by apatations related to hemiparesis after stroke. The purpose of this study was to examine the relationship between daily walking activity and spatiotemporal gait asymmetries post-stroke. We hypothesized that individuals with the greatest asymmetries would show the greatest impairment in daily walking activity. Methods: To obtain a measure of activity level, twenty-five persons with chronic stroke wore a StepWatch Activity Monitor for at least 4 days. Steps per day (SPD) was averaged across the wear period. Gait asymmetry was measured as subjects walked at their self-selected speed across the GaitMat instrumented walkway. Following the collection of 5 runs with 3 strides each, the descriptors of gait asymmetry were averaged and used to analyze the relationship to SPD. Descriptors of gait asymmetry included: step length asymmetry (SL), stance time asymmetry (StT), and swing time asymmetry (SwT). Results: The combined variables of spatiotemporal asymmetry are significantly related to SPD (r=0.598, p=.023). Individually, there is a trend for a relationship between SwT asymmetry and SPD (r2 =-0.410, p=.052). Conclusions: These results suggest that in persons poststroke, there is a relationship between spatiotemporal asymmetry and decreased walking activity. To better understand this relationship, future studies should examine whether there is a relationship between improvements in swing time asymmetry and walking activity with rehabilitation after stroke.

32 CHANGES IN MUSCLE CONTRIBUTION TO SUPPORT AND PROPULSION POST GAIT-RETRAINING IN STROKE VICTIMS

Reza Khoelilar, Jill S. Higginson

Mechanical Engineering

Stroke is a leading cause of disability in US and often leads to gait impairment. The complexity of the human musculoskeletal system enables fine motor control but makes treatment difficult. Understanding the underlying mechanisms and individual muscle contributions to pathological gait is essential for designing optimal treatments. The objective of this study was to use computational simulations to help elucidate the functional rolls of muscles in stroke gait and detect how rehabilitation has affected individual muscles. Stroke patients were recruited and divided evenly to undergo two forms of gait-retraining; Body Weight Supported Treadmill Training (BWSTT) and Active Leg Exoskeleton Training (ALEX), which uses assist as needed paradigm. Subject specific 3D simulations were built using motion capture data and ground reaction forces before and after training sessions. Analyses were performed to detect changes in muscle force, muscle potential-a quantitative measure of muscles ability to accelerate center of mass based on posture alone-and muscle induced acceleration. Preliminary results for BWSTT indicate an increase in the contribution of Gluteus Maximus to support in stance phase as well as increased support by Gastrocnemius and higher forward acceleration by Soleus pre- swing. ALEX subjects also showed an increase in the support of the center of mass in stance phase by Gluteus Maximus and support of the center of mass pre-swing by Gastrocnemius but unlike BWSTT, no marked improvements were seen in the contribution of Soleus to forward acceleration of the center of mass. Detection of differences in muscle function and how each treatment affects individual muscles may lead to targeted rehabilitation choices for stroke victims based on their individual modes of impairment.

33 THE RELATIONSHIP BETWEEN WALKING SPEED AND INTENSITY OF DAILY WALKING ACTIVITY IN INDIVIDUALS POST-STROKE

Brian A. Knarr¹, Margaret A. Roos², Darcy S. Reisman²

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Stroke related disability is a common consequence and risk factor for physical inactivity. A lack of physical activity, especially when limited to low intensity activity, can have health consequences for individuals post-stroke. The purpose of this study was to examine how walking function for individuals post-stroke (as assessed by self-selected walking speed (SSWS)) relates to the intensity of daily walking activity. A StepWatch Activity Monitor (SAM) was calibrated to a subject's height and weight and placed above the subject's ankle on the non-paretic leg. Participants wore the SAM during all waking hours (except bathing and swimming) for 3-5 consecutive days. Sampling intervals of the SAM data were normalized across all subjects to 10 seconds. Walking intensity, or the average step rate during each bout of walking was calculated as the total number of steps during a bout divided by the bout length. A threshold for high intensity walking was calculated on a subject specific basis as 2/3 of the maximum walking intensity a subject reached for any 10 second epoch over the collected days. Ninety-eight subjects (Male: n=59, 63.8 ± 10.3 years old, SSWS: 0.67 ± 0.29 m/s, 43.6 ± 58.1 months post-stroke) participated in this study. Self-selected and fastest walking speeds and were positively correlated with several variables including maximum walking intensity, and total time spent and steps taken at high intensity. Interestingly, there was no relationship between walking speed and continuous time spent at high intensity, suggesting that individuals with greater walking speed may walk at high intensity more frequently, but not necessarily for a longer continuous time.

34 CHANGES IN FUNCTIONAL ROLES OF POST-STROKE HIP MUSCLES BETWEEN HOUSEHOLD AND COMMUNITY AMBULATORS

John Ramsay, Thomas Buchanan, Jill Higginson

Understanding the factors limiting speed progression and the compensatory mechanisms utilized to achieve higher walking speeds is important for stroke rehabilitation. The purpose of this study was to use a hybrid simulation method to determine hip muscle compensatory mechanisms utilized by fast walkers that may be used as therapeutic guidelines for facilitating an increase in walking speed for slow post-stroke walkers. Kinematic, kinetic, and electromyography (EMG) data of 6 post-stroke subjects, split into two ambulatory speed groups (3 household and 3 community), were used for this study. The hybrid simulation method utilizes an EMG-driven model to estimate subject-specific muscle activation patterns and individual muscle parameters for fourteen knee and ankle muscles. Muscles were constrained by these updated parameters and activation patterns and computed muscle control was used to estimate the remaining hip muscle activations and muscle forces. Resultant individual hip flexion/extension and abduction/adduction muscle moments were estimated during swing. In general, we found that muscle function becomes less specialized for community ambulators during swing. More specifically, for household ambulators, the iliopsoas primarily function as hip flexors; however, for community ambulators, these muscles also function as hip adductors. Additionally, the gluteus medius showed an increase in moment magnitude in community ambulators. Neuromuscular training or electrical stimulation techniques that aim to decrease the specialization of muscle function may be beneficial for household ambulators who are determined to walk faster.

35 FACTORS THAT ATTRIBUTE BODY WEIGHT THROUGH A TREADMILL TRAINING INTERVENTION IN POST-STROKE INDIVIDUALS

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Stroke is the fourth leading cause of death in the United States with about 795,000 Americans suffering from a new or recurrent stroke each year. Non-modifiable risk factors include: age, gender, family history, and prior stroke. Modifiable risk factors include: cardiovascular issues, sedentary lifestyle, and being overweight or obese. Previous studies have investigated variables that change body weight in healthy individuals. However, few studies that look at body weight changes in stroke survivors. The purpose of this study is to investigate factors affect body weight changes in a treadmill training intervention. Methods: 40 subjects with chronic stroke participated in a treadmill training intervention, in which subjects walked 30 minutes on the treadmill and six minutes overground walking. Subject's body weight, step activity, weight questionnaire, and season of training were collected.

The baseline body weight was 91.65 ± 21.34kg. The baseline number of steps taken per day was 5936 ± 3562 steps. There is no significant correlation between changes in step activity and body weight change. There is a significant correlation between seasonal changes and percent body weight change (P = .038, r² = .114). Limitation: Body weight changes was not the main outcome goal of the treadmill intervention. Conclusion: Seasonal changes affects body weight changes. Future studies should look at different body measurements throughout a treadmill intervention.

36 LINEAR ACCELERATION OF THE HEAD DURING PURPOSEFUL HEADERS IN MALE AND FEMALE COLLEGIATE SOCCER PLAYERS

Nathaniel Rosal, PI., Jaclyn Caccese, Graduate Student Mentor., Thomas Kaminski, Faculty Advisor.

In the United States, a growing concern of the risks of heading a soccer ball and moreover by the risk of concussions is affecting players of different levels. Interestingly enough, women's soccer players are almost two times as likely to sustain a concussion as men's players. This may be because of neck strength, head mass, and/or other factors that affect head acceleration. Therefore, the purpose of this investigation is to compare linear acceleration of the head in collegiate male and female soccer players during purposeful heading drills.

Ten male (20.3y/o ± 2.3, 178.4cm ± 6.0, 72.3kg ± 8.4) and ten female (18.2y/o ± 0.7, 170.2cm ± 4.2, 61.8kg ± 4.8), collegiate soccer players participated in this investigation. TriAx accelerometers were placed in headbands, worn by subjects throughout testing, to measure linear acceleration of the head. Three trials of two heading types were examined during testing. The first was a linear header, where the ball was to be sent back in the same direction from which it came. Next was a rotational header, where the subject was instructed to head the ball off to their dominant side. In each situation, the ball was traveling at the subject at 12.5m/s.

Anthropometric measurements of neck length, girth, and head mass and isometric neck strength were used as covariates when comparing gender differences.

Average accelerations were 15.7 ± 2.2 and 18.2 ± 4.2G's for the linear and rotational on headers, respectively, in the male population. Average accelerations were 16.3 ± 3.7 and 19.3 ± 4.0G's for the linear and rotational on headers, respectively, in the female population. These results were not significantly different (p = 0.690 and 0.576), suggesting that head acceleration in males and females may not account for the difference in rate of incidence of concussions.

POSTER PRESENTATIONS

Robotics

37 DESIGN AND CONTROL OF BIO-INSPIRED LEGGED ROBOTS

By: Alex Revell, Konstantinos Karydis, Prasanna Kannappan, Dr. Herbert Tanner, and Dr. Ioannis Poulakakis

Legged robots have a distinct and significant advantage over wheeled robots when faced with rough terrain and other obstacles, as would be present in a search-and-rescue mission or reconnaissance operation.

The intent of this design project was to create an inexpensive, easily assembled walking sensory platform that can overcome rough terrain and small obstacles.

The final design features a crank-driven leg linkage invented by Theo Jansen. Eight legs are driven by two DC metal gearmotors via a geared transmission system. This differential-drive robot is largely constructed from 3D printed components, in order to reduce weight, cost, and machining time.

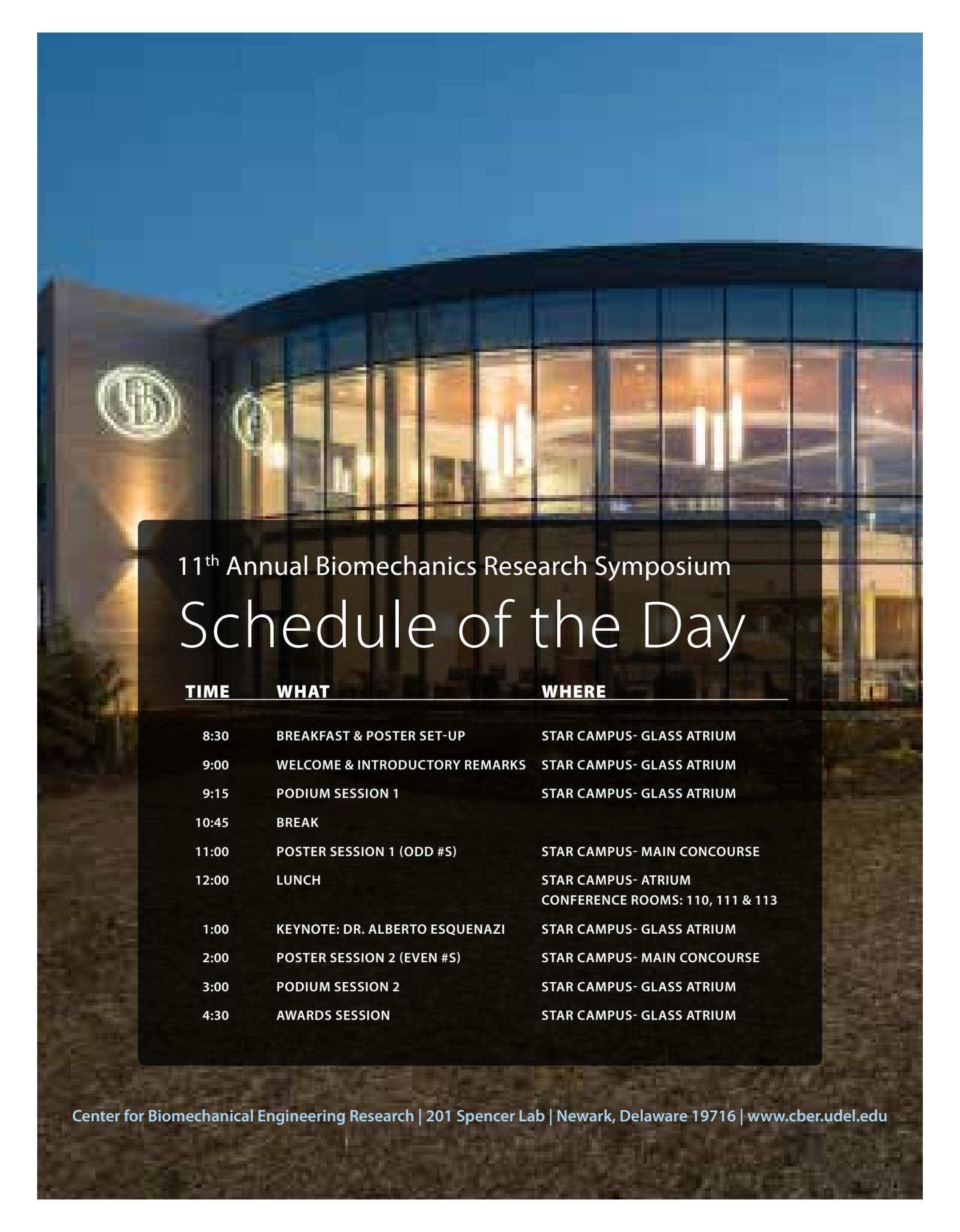
An on-board computer primarily controls the robot using Wi-Fi, with additional components such as a motor driver, power regulator, and USB hub. Three lithium ion batteries power the two motors and the on-board electronics. The two sensors that were placed on the platform for testing were a laser scanner and HD webcam. In addition to the open space on the baseplate, a lid was added to provide a mounting surface for the sensors and USB hub.

Including electronics, the final design weighed 4.6 lbs and cost less than \$400 to assemble. The approximate dimensions are as follows: 14" long, 8.5" wide, and 7" tall. Further evaluation is ongoing, and several tests are planned to assess various capabilities of the robot. Some of the tests include measuring maximum linear speed on a few different surfaces, finding the maximum obstacle height that the robot can climb over, and examining the steepest incline that the robot can traverse.

The potential of walking robots is still being uncovered, and this platform will be a useful tool for further improving what they are capable of.

Notes

Two columns of horizontal lines for taking notes.



11th Annual Biomechanics Research Symposium Schedule of the Day

TIME	WHAT	WHERE
8:30	BREAKFAST & POSTER SET-UP	STAR CAMPUS- GLASS ATRIUM
9:00	WELCOME & INTRODUCTORY REMARKS	STAR CAMPUS- GLASS ATRIUM
9:15	PODIUM SESSION 1	STAR CAMPUS- GLASS ATRIUM
10:45	BREAK	
11:00	POSTER SESSION 1 (ODD #S)	STAR CAMPUS- MAIN CONCOURSE
12:00	LUNCH	STAR CAMPUS- ATRIUM CONFERENCE ROOMS: 110, 111 & 113
1:00	KEYNOTE: DR. ALBERTO ESQUENAZI	STAR CAMPUS- GLASS ATRIUM
2:00	POSTER SESSION 2 (EVEN #S)	STAR CAMPUS- MAIN CONCOURSE
3:00	PODIUM SESSION 2	STAR CAMPUS- GLASS ATRIUM
4:30	AWARDS SESSION	STAR CAMPUS- GLASS ATRIUM