Biomechanics Research Symposium

May 14, 2004

This is our first Biomechanics Research Symposium, sponsored by the Center for Biomedical Engineering Research (CBER). This symposium celebrates the considerable and varied biomechanics work at the University of Delaware. Over 85 people have registered to attend this symposium and there will be 50 poster and podium presentations given, representing the research from the Departments of Mechanical Engineering, Physical Therapy, Biological Sciences, Health, Nutrition & Exercise Sciences, and Bioresources Engineering. In addition, many of the faculty and students participating are a part of our interdisciplinary Graduate Program in Biomechanics and Movement Science.

Our keynote address will be given by Dr. David Lloyd of the University of Western Australia. Dr. Lloyd is renowned for his work in musculoskeletal modeling and will be discussing its application to the study of osteoarthritis.

We are also pleased to have join us Dr. Zev Rymer of Northwestern University, Dr. Bob Gregor of Georgia Tech, and Dr. Mark Grabiner of University of Illinois, Chicago. They are members of our CBER external advisory committee and will be judging the student research competitions. Awards will be given out for best undergraduate student poster, best graduate student poster, and best graduate student presentation.

Schedule of the Day

Begin	End	What	Where
8:30	9:00	Breakfast & Poster set-up	SPC 123
9:00	10:00	Posters	Spencer Hall or Outside
10:10	11:00	Keynote: Dr. David Lloyd	Gore 104
11:00	12:30	Posters	Spencer Hall or Outside
12:30	1:00	Lunch (buffet)	SPC 123
1:00	2:30	Platform Presention Session I	SPC 114
2:30	2:45	Coffee Break	SPC 123
2:45	4:00	Platform Presention Session II	SPC 114
4:00	4:15	Awards	SPC 114

Platform Presention I

1:00	1:15	Banala, Sai
1:15	1:30	Butler, Robert
1:30	1:45	Kebaetse, Mike
1:45	2:00	Mizner, Ryan
2:00	2:15	Permual, Ramu
2:15	2:30	Dong, Shufang

Platform Presention II

2:45	3:00	Barrance, Peter
3:00	3:15	Ramsey, Dan
3:15	3:30	Fattah, Abbas
3:30	3:45	Krishnamoorthy, Vijaya
3:45	4:00	Milner, Clare

Platform Presentations

Session I

#	Presenter/First Author	Rank	Title
1	Banala, Sai	Grad Student	A Passive Leg Orthosis for Robotic Rehabilitation
2	Butler, Robert, J	Grad Student	The effect of wedged orthotics on hip and ankle mechanics
3	Kebaetse, Maikutlo, B	Grad Student	Paralyzed skeletal muscle performance during electrically elicited, repetitive, non-isometric contractions
4	Mizner, Ryan, L	Grad Student	Impact of Quadriceps Strength on Movement Patterns after Total Knee Arthroplasty
5	Perumal, Ramu	Grad Student	Mathematical model that predicts lower leg motion in response to electrical stimulation
6	Dong, Shufang	Grad Student	Versatile Rehabilitation Device with Variable Resistance and Joint Motion Control

Session II

#	Presenter/First Author	Rank	Title
7	Barrance, Peter, J	Post-Doc	Using dynamic MRI to measure the effects of ACL deficiency on knee kinematics during activity
8	Ramsey, Dan, K	Post-Doc	Effect of Anatomical Realignment on Muscle Function in Medial Knee OA
9	Fattah, Abbas	Research Scientist	Design of a passive assistive device for sit-to-stand tasks
10	Krishnamoorthy, Vijaya	Post-Doc	Joint coordination during quiet stance: Effects of vision
11	Milner, Clare, E	Post-Doc	Does sustaining a lower extremity stress fracture alter lower extremity mechanics in runners?

Posters

#	Presenter/First Author	Rank	Title
12	Agrawal, Abhishek	Grad Student	Effect of Gravity Balancing on Biped Stability
13	Alicknavitch, Michael	Staff	Osteoarthritis (OA): Do changes in underlying bone accompany cartilage healing?
14	Bhat, Anjana, N	Grad Student	Longitudinal changes in spatio-temporal patterns of early arm movements
15	Cashen, Caitlin, M	Undergrad	The effect of laterally-wedged orthoses on gait and function in patients with medial knee osteoarthritis
16	Cohen, Shay	Grad Student	Developing and testing of an EMG-driven model to estimate ankle moments and muscle forces
17	Crenshaw, Stephanie J	Grad Student	Laterally Wedged Insoles Reduce Knee Pain During Functional Activities in Subjects with Medial Knee OA
18	Dierks, Tracy, A	Grad Student	Lower Extremity Joint Coupling and Patellofemoral Pain During Running
19	Ding, Jun	Faculty	Using a Mathematical Model to Predict the Isometric Force-Intensity Relationship
20	Fattah, Abbas	Research Scientist	On the Design of Gravity Balanced Human Legs using Passive Orthoses
21	Fitzgibbons, John, T	Undergrad	Investigating Sensor Technologies to Measure Finger Movements During Physical Therapy
22	Fresconi, Frank, E	Grad Student	In-vitro measurement of expiration flow in the upper respiratory airways.
23	Gardinier, Joseph, D	Grad Student	Using low cost force sensors to measure elbow joint moments: trade-off between cost and accuracy
24	Glime, Lauren, J	Undergrad	Single and Dual Motor Task Coordination Development
25	Guo, Mengtao	Grad Student	The Effect of Increasing Toe-out Angle on the Knee Adduction Moment during Walking and Stair Climbing in Healthy People
26	Heathcock, Jill, C	Grad Student	Relative Interlimb Kicking Frequency of Full-term and Preterm Infants in the Mobile Paradigm
27	Herseim, Richard, M	Undergrad	Device to Simulate Hip Impact During Human Falls
28	Hsu, Wei-Li	Grad Student	Reliability of EMG Recordings using an Alternative Test of MVIC
29	Hurd, Wendy, J	Grad Student	Development of Dynamic Knee Stability
30	Jian, Pankaj	Grad Student	Ultrasound contrast agents: experiments and modeling
31	Johnson, Brian, B	Grad Student	Manufacturing and performance of carbon nanotube/high density polyethylene composites

#	Presenter/First Author	Rank	Title
32	Kesar, Trisha	Grad Student	Effects of frequency and intensity modulation on fatigability of skeletal muscle during electrical stimulation.
33	Lei, Fulin	Grad Student	Modeling of Articular Cartilage by Fibril-reinforced Poroelastic Model
34	Lei, Fulin	Grad Student	An Inverse Analysis of Articular Cartilage in Unconfined Compression
35	Lobo, Michele, A	Grad Student	General and Task-related Experiences Affect Early Object Interaction
36	Moore, James, F	Undergrad	Development of a Standard Test Methodology for Hand-Held Power Tools to Assess Hand-Arm Vibration Characteristics
37	Muhlenforth, Daniel, R	Undergrad	Evaluation of the Hand-Arm Vibration Characteristics of New Hand-Struck Tool Designs Using High Performance Engineering Polymers
38	Pabreja, Priya	Grad Student	The effects of age and reference condition on phase locking and phase error in a dual motor task
39	Peterson, Stephanie, C.	Grad Student	Morphological and Neural Contributions to Changes in Quadriceps Strength after Total Knee Arthroplasty
40	Ramsey, Dan, K	Post-Doc	Reflexive muscle responses during valgus perturbations after anatomic tibiofemoral realignment
41	Roberts, Dustyn, P	Grad Student	Correlation between EMG and Pennation Angle as Determined using Ultrasound
42	Schmitt, Laura, C	Grad Student	Knee Stability in Patients with Medial Knee OA
43	Tate, Christine, M	Undergrad	Subject-Specific Lower Extremity Muscle Morphology Evaluated from Magnetic Resonance Imaging
44	Tseng, Ya-weng	Grad Student	The Effect of Workspace on the Use of Motor Abundance
45	Turka, Christina, M	Grad Student	Mechanical Characterization of a Cartilage Tissue Equivalent during Its Development
46	Wilson, John D.	Grad Student	The role of lumbopelvic strength in lower extremity injury prevention and overall athletic performance: gender differences
47	Wolos, Gregory, J	Grad Student	Experimental Measurement of Particle Diffusion and Three Dimensional Strain Field in Articular Cartilage Under Static Compression
48	Zhang, Le	Grad Student	Flow-Dependent Neutral Solute Transport in Cartilage
49	Zhou, Hehe	Grad Student	Analysis of Rotator Cuff Tears using Cine-phase Contrast MRI
50	Zifchock, Becky, A	Grad Student	Gender Differences in Arch Height

PLATFORM PRESENTATIONS

Session I

1 A PASSIVE LEG ORTHOSIS FOR ROBOTIC REHABILITATION

Sai K. Banala, Sunil K. Agrawal, Abbas Fattah, Katherine Rudolph, John Scholz
Mechanical Systems Laboratory , Department of Mechanical Engineering and Department of Physical Therapy, University of Delaware, Newark, DE 19716, agrawal@me.udel.edu

A number of methods can be found in the literature to gravity balance a machine. In this paper we use hybrid method to achieve gravity balancing.
Hybrid method employs a mechanism to locate center of mass of the robot in conjunction with springs. This method is used to develop a rehabilitation device which compensates the effect of gravity on a human leg. For a quantitative evaluation of the performance of the device, electromyograph data of the muscles involved in the motion of leg were collected and analysed. This data showed that the machine could be used for gravity balancing of the leg and could be potentially used for rehabilitaion of patients.

2 THE EFFECT OF WEDGED ORTHOTICS ON HIP AND ANKLE MECHANICS

R.J. Butler, I. McClay Davis FACSM, T. Royer, S. Crenshaw, E.S. Mika
University of Delaware, Newark, DE email: rbutler@udel.edu

Laterally wedged orthotic devices have been reported to be an effective treatment for medial knee osteoarthritis. These devices have been reported to reduce the peak frontal plane moment and angle at the knee but no studies have evaluated changes in the frontal plane at the hip or ankle. PURPOSE: To evaluate frontal plane hip and ankle mechanics when patients with medial knee osteoarthritis walk with and without an individually prescribed laterally wedged orthotic device. HYPOTHESES: It was hypothesized that the peak eversion angle and peak inversion moment would be greater in the wedged condition and that no changes would be observed in the mechanics at the hip. METHODS: 15 patients with medial knee osteoarthritis of a K-L grade of two or greater were evaluated for this study. All subjects were given an orthotic with an individually determined amount of lateral wedging determined by the amount of wedging that reduced pain the most during a lateral step down test. Comparisons were made between the wedged (W) and non-wedged (NW) conditions. RESULTS: Subjects had increased peak eversion (W: 6.22 deg vs. NW: 4.22 deg ; p=0.00) and eversion excursion (W: 13.56 deg vs. NW: 9.65 deg ; p=0.00) in the wedged condition. As well, in the wedged condition there was an increased peak inversion moment (W: -0.068 km/kg*ht vs. NW: -0.029 Nm/kg*ht ; p=0.00). No changes were noted in joint moments or peak angles at the hip. CONCLUSION: As a result of the wedged orthoses changes previously noted in knee mechanics were more related to changes at the ankle than at the hip. While no subjects have experienced adverse side effects from the increased eversion, the long term effects of this change should be monitored.

3 PARALYZED SKELETAL MUSCLE PERFORMANCE DURING ELECTRICALLY ELICITED, REPETITIVE, NON-ISOMETRIC CONTRACTIONS

Kebaetse MB[1], Binder-Macleod SA[1], Lee SCK[2], and Johnston T[2].
[1]Biomechanics and Movement Science, University of Delaware; [2]Shriners Hospitals for Children, Philadelphia

A stimulation frequency between ~ 20 and 50 Hz is typically used to activate paralyzed muscles during functional electrical stimulation (FES). Lower frequencies produce lower forces and less fatigue; higher frequencies produce higher forces and greater fatigue. Previously, we showed that activating healthy human skeletal muscle with a combination of frequencies that included a low frequency followed by a higher frequency improved endurance more than either frequency alone during repetitive, non-isometric contractions. The purpose of the present study was, therefore, to determine the effect of combining different frequencies on the ability of paralyzed quadriceps muscle to produce a 50° knee excursion repetitively when starting at 90° of flexion. Data were collected from children (aged 11-25 years) with motor-complete spinal cord injuries using ~1-s long stimulation trains. With subjects sitting on a KinCom dynamometer set to the isotonic mode, the protocols tested were: 20-Hz followed by 66-Hz trains (C20+66), C33+66, and 66-Hz trains alone (C66). For each frequency, stimulation was repeated until the knee failed to produce the 50° excursion. The C20 and C33 produced comparable numbers of excursions (41.0±12.6 (means ± S.D.) and 42.0±12.3, respectively) and both produced more excursions than the C66 protocol. The C20+66 and C33+66 protocols produced 51.4±15.0 and 44.9±13.6 excursions, respectively, and the C20+66 was the best protocol overall. These results suggest that stimulation strategies that start with low frequencies and switch to higher frequencies may improve the ability of FES applications to perform repetitive, non-isometric contractions.

4 IMPACT OF QUADRICEPS STRENGTH ON MOVEMENT PATTERNS AFTER TOTAL KNEE ARTHROPLASTY

Mizner RL, Snyder-Mackler L.
University of Delaware. Physical Therapy Department.

Purpose: Total knee arthroplasty (TKA) has been successful at reducing pain, but has not achieved comparable improvements in functional performance. The cause of persistent disability in this patient population remains vague. Quadriceps weakness is a common and persistent condition following surgery. Our purpose was to determine the impact of quadriceps weakness on movement patterns after TKA.
Methods: Twelve subjects (mean age=62, BMI=29) with their pathology isolated to unilateral TKA were tested 3 months after surgery. Average knee extension range was 0.5 degrees and flexion was 117 degrees. Quadriceps strength was assessed isometrically using a burst superimposition technique. All subjects underwent an examination to collect kinematics, kinetics, and EMG during gait and sit-to-stand (STS).
Results: The involved quadriceps was significantly weaker than the uninvolved (62% of uninvolved). During STS, subjects shifted their weight away from the operated limb. The ratio of weight distribution between legs during standing and the relative contribution of the knee moment to the total support moment were correlated with the involved limb's quadriceps strength. In addition, there were lower normalized quadriceps and hamstring activity in the involved leg compared to the uninvolved leg. In gait, the involved limb had a significantly lower knee flexion angle during weight acceptance which corresponded to lower integrated quadriceps muscle activity. All patients reported no knee pain during motion analysis testing. Conclusions: Quadriceps weakness in patients with TKA has a substantial impact on the movement patterns and performance of the knee during sit-to-stand and walking activities. The weakness induced patterns described in this study would likely play a significant role in functional outcomes after surgery.

5 MATHEMATICAL MODEL THAT PREDICTS LOWER LEG MOTION IN RESPONSE TO ELECTRICAL STIMULATION

Ramu Perumal, Anthony S. Wexler, and Stuart A. Binder-Macleod
Departments of Mechanical Engineering and Physical Therapy

Direct electrical activation of skeletal muscles of patients with upper motor neuron lesions can restore functional movements, such as standing or walking. Because responses to electrical stimulation are highly nonlinear and time varying, accurate control of muscles to produce functional movements is very difficult. Accurate and predictive mathematical models can facilitate the design of stimulation patterns and control strategies that will produce the desired force and motion. Previously, we developed a Hill-type model that predicted the force responses of the quadriceps femoris muscle to a wide range stimulation frequencies and patterns when the muscle was held at different lengths and when the leg was moved at a variety of constant velocities The purpose of this study was to validate our model during nonisometric contractions when the leg was allowed to move freely in response to electrical stimulation. Our results showed that the model could accurately predict the angular position and velocity of the lower leg when the muscle was stimulated with wide range of clinically relevant stimulation frequencies and patterns and with different loads placed around the ankle joint.

6 VERSATILE REHABILITATION DEVICE WITH VARIABLE RESISTANCE AND JOINT MOTION CONTROL

Shufang Dong and Jian Sun
Department of Mechanical Engineering, University of Delaware

Resistance exercise has been widely reported to have positive rehabilitation effects for patients with neuromuscular and orthopaedic conditions. This presentation presents the design of a versatile rehabilitation device in the form of a rotating joint arm mounted on the adjustable seat which make the passive strengthening of several joint systems possible. A well designed magnetorheological damper produces the prescribed resistive force. Considering the human-machine interaction, a multi-loop nonlinear control for regulating the resistive force and attaining a variable joint motion exercise has also been studied. In addition, we propose a dynamically online updating muscles contraction model incorporating viscous properties and the fatigue factor. The device provides both isometric and isokinetic strength training for the joint system.

Session II

7 USING DYNAMIC MRI TO MEASURE THE EFFECTS OF ACL DEFICIENCY ON KNEE KINEMATICS DURING ACTIVITY

Peter J. Barrance*, Glenn N. Williams^, Thomas S. Buchanan*
*Center for Biomedical Engineering Research, Department of Mechanical Engineering, University of Delaware; ^ Graduate Program in Physical Therapy and Rehabilitation Science; UD BIOMS program Ph. D. graduate, 2004

According to one estimate, approximately 80,000 ruptures of the anterior cruciate ligament (ACL) occur annually in the United States. This injury results in well documented and clinically observable changes in passive joint laxity; however, the alterations to joint kinematics during activity are less well understood. It has been postulated that altered knee joint kinematics in people with ACL deficiency and those who have undergone ACL reconstructions promote the development of knee osteoarthritis; hence, study of pre- and post-operative joint kinematics is important to assess the effectiveness of treatment of these injuries. An in vivo joint kinematics measurement technique, in which cine phase contrast dynamic MR imaging was combined with a specially developed kinematic tracking method, will be described. A validation study performed using a specially developed device, as well as a human subjects repeatability study, will be described. Results on the six degree of freedom knee kinematics measured in 16 pre-operative ACL-deficient subjects and 16 age and activity matched control subjects as they performed a

repetitive knee extension exercise will be presented. ACL-deficient subjects exhibited more anterior positioning of the tibia in the injured knees relative to the control knees, as well as trends of increased rates of anterior tibial translation and decreased external tibial rotation. Preliminary findings on the kinematics in a subset of the same ACL-deficient subjects after reconstruction will also be described.

8 EFFECT OF ANATOMICAL REALIGNMENT ON MUSCLE FUNCTION IN MEDIAL KNEE OA

Ramsey DK, Lewek M, Rudolph KS, Snyder-Mackler L.
Department of Physical Therapy

Introduction: The purpose of this study was to determine the effect of joint realignment on muscle function and movement patterns in patients with medial compartment knee osteoarthritis (MKOA). Methods: Nine subjects with MKOA and genu varum were tested prior to (PRE) and one year following (POP) Opening Wedge-High Tibial Osteotomy (OW-HTO). Nine healthy age and gender-matched subjects (NORM) were compared. Knee alignment and joint laxity were derived from radiographs. Quadriceps strength was assessed using a KinCom Dynamometer. Motion analysis was used to assess kinematic and kinetic patterns. To evaluate muscle function, EMG were collected from the medial and lateral hamstrings, vastus medialis (VM), vastus lateralis, and lateral and medial gastrocnemius (MG). Results: Following OW-HTO, knee adduction angle and moments were significantly reduced. Medial laxity was significantly lower (p = 0.02) but comparable to the NORM group (p = 0.394). Quadriceps weakness and diminished knee flexion excursions persisted. Both PRE (p=0.013) and POP (p=0.005) quadriceps strength were significantly lower than controls. During weight acceptance, knee flexion excursions were unchanged (p = 0.451); both were less than the NORM group, (p = .020). Following realignment, there was a trend towards lower medial VMMG co-contraction during gait (p = 0.113) and a trend towards significance between the PRE group and the NORM group (p = 0.122). No significant differences were evident between the NORM and POST group. Correlations between knee flexion excursion and quadriceps strength both PRE (p = 0.027) and POP (p = 0.089) and between VMMG co-contractions and quadriceps strength PRE (p = 0.010) and POP(p = 0.087) were observed. Discussion: Persistent quadriceps weakness and reduced knee flexion combined with medial muscle co-contraction before and after realignment suggest the movement strategy may perpetuate joint destruction. Addressing impaired quadriceps function by improving strength and reducing medial muscle co-contraction could improve shock absorption at the knee, a vital step in slowing the progression of MKOA.

9 DESIGN OF A PASSIVE ASSISTIVE DEVICE FOR SIT-TO-STAND TASKS

Abbas Fattah, Ph.D., Sunil K. Agrawal, Ph.D., and John Fitzgibbons
Mechanical Systems Laboratory, Department of Mechanical Engineering, University of Delaware, Newark, DE 19716, fattah, agrawal@me.udel.edu

Several proposals and assistive devices for helping the elderly people and patients during standing up have been reported. Most of the these research works used functional electrical stimulation or an active (powered) system to augment standing up capabilities of impaired people. The goal of our research is to propose a design of a passive gravity-balanced assistive device for increasing the ability to stand up in elderly and impaired people.
The joint torques in hip, knee and ankle are computed using inverse dynamic model during standing up for a paraplegic patient. The joint torque comprises the dynamical torque due to the inertia forces, a passive toque due to the muscles and gravitational torque. It has been observed that the contribution to the joint torques by the gravitational torque is dominant. On the basis of this result, a gravity balanced assistive device is proposed for the impaired people. This passive design uses a hybrid method to identify the center of mass of the system using auxiliary parallelograms and then attach appropriate springs to vanish the total potential energy of the

system due to the gravity during standing up. A prototype with the underlying principles is currently being fabricated at the University of Delaware.

10 JOINT COORDINATION DURING QUIET STANCE: EFFECTS OF VISION

Vijaya Krishnamoorthy PhD, PT, Jeng-Feng Yang MS, PT, John P Scholz PhD, PT
Department of Physical Therapy and Biomechanics & Movement Science Program

Stabilization of the center of mass (CM) is considered to be an important goal of the postural control system. Coordination of several joints along the human 'pendulum' is required to achieve this goal. In this project, we studied the coordination among body segments with respect to CM stabilization during a quiet stance task, and the effects of vision on CM stability using the uncontrolled manifold (UCM) approach. Here, the UCM is a subspace spanning all joint combinations resulting in a desired CM position. The variance of joint angles within the UCM is goal equivalent variance or GEV and the variance of joint angles in a subspace orthogonal to the UCM is non-goal equivalent variance or NGEV. Six subjects participated in the study and were asked to stand quietly on a narrow wooden block supporting only the mid-foot, with either open (EO) or closed (EC) eyes in separate trials. Instant equilibrium points (IEPs) in the center of pressure (CP) trajectory were determined when the body is instantly stable and the CP data was decomposed into its rambling and trembling components. The joint angle, CM and CP data were divided into segments of equal length beginning and ending in an IEP. The joint angle vector was computed at each point in time and projected onto the UCM and the subspace orthogonal to the UCM. In both the EO and EC conditions, GEV was significantly higher than NGEV. Although joint configuration variability was higher in the EC condition, this was due to a selective increase in GEV compared to the EO condition. High cross-correlations between NGEV and the rambling trajectory (causing a shift in the CM) as well GEV and the trembling trajectory (stabilizing the CM) were also found. These results demonstrate the ability of the control system to selectively "channel" motor variability into goal equivalent directions that stabilize the CM position. This effect was enhanced when the task was made more challenging in the absence of vision.

11 DOES SUSTAINING A LOWER EXTREMITY STRESS FRACTURE ALTER LOWER EXTREMITY MECHANICS IN RUNNERS?

Clare E. Milner, Irene S. Davis*^ and Joseph Hamill"*
*Dept of Physical Therapy, University of Delaware, ^Joyner Sportsmedicine Institute, Lexington, KY, "Dept of Exercise Science, University of Massachusetts.

Lower extremity stress fractures (SF) are common in runners, particularly in females who sustain about twice as many as males. SF is one of the most serious running injuries, requiring 6 to 8 weeks rest, and the risk of reinjury is high. There is some evidence that SF are related to running gait mechanics. The effect of a previous SF on mechanics is unknown and could be a factor in the high rate of reinjury in this group. The aim of this study was to determine whether pre-injury running mechanics are altered following the occurrence of and recovery from SF. Currently uninjured adult female runners, typically running at least 20 mpw, are recruited into a 2 year longitudinal study. An instrumented gait analysis is performed on entry into the study. 3D kinematics and kinetics are calculated for both lower limbs. Subjects are then followed monthly for 2 years. All participants who sustain an SF are asked to return to the laboratory for a second instrumented gait analysis. To date, 6 runners have sustained an SF or tibial stress reaction. These were compared to a matched control group of uninjured runners. Runners who sustain an SF have higher lower extremity load rates and shock prior to injury in comparison with controls. Post-injury subjects adopted a more risky gait, with further increases in lower extremity load rates and shock. This finding may explain the high incidence of reinjury following an SF in runners. These preliminary data suggest that interventions to reduce loading post fracture need to be developed. (Supported by Dept of Defense grant DAMD17-00-1-0515.)

POSTERS

12 EFFECT OF GRAVITY BALANCING ON BIPED STABILITY

Abhishek Agrawal and Sunil K. Agrawal
Mechanical Systems Laboratory
Department of Mechanical Engineering, University of Delaware, Newark, DE 19716

Gravity balancing is often used in industrial machines to decrease the actuator efforts during motion. Through the use of rehabilitation devices one can also partially balance the leg during motion with the goal to reduce net joint torque during motion. However, it is not clear as to what are the effects of such devices on legged locomotion. This paper aims to study the effect of such gravity balancing devices on the motion of bipeds during walking.

13 OSTEOARTHRITIS (OA): DO CHANGES IN UNDERLYING BONE ACCOMPANY CARTILAGE HEALING?

Mary C. Farach-Carson, Michael G. Alicknavitch, George R. Dodge, John E. Novotny
Biological Sciences [MCFC, MGA], Mechanical Engineering [JEN], University of Delaware, Newark, DE and AI duPont Childrens Hospital/Nemours Foundation, Wilmington, DE (GRD)

The absence of objective biochemical markers to OA is a major barrier to clinical and therapeutic research, and very few reliable antibody markers are in existence for testing in the rabbit experimental model of OA. The present study investigates the hypothesis that changes in underlying bone accompany changes in cartilage during the healing phase in experimentally induced OA in skeletally mature rabbit knees. The expression of extracellular matrix proteins and biochemical markers of tissue growth will be monitored, with particular attention to the role of heparin binding growth factors (HBGFs), heparanase and heparan sulfate proteoglycans (HSPGs), and including tissue location, abundance and temporal expression. This will be executed using indirect immunofluorescence techniques and confocal imaging before and during the healing process. Initial studies have been directed toward development of reagents suitable for use in the rabbit, including antibody probes for two HSPGs, perlecan and syndecan, standard markers for bone and cartilage, collagens I, II & X, for the chondroitin sulfate proteoglycan aggrecan, for the HBGFs VEGF and FGF-2, and for the enzymes involved in growth factor delivery including metalloproteinases (MMP-1, 3, 8, and 13) and heparanases. All samples undergo fixation and decalcification prior to paraffin embedding and tissue sectioning. Normal, rabbit knees and control mouse long bone sections have been utilized for development and testing of antibody probes, for determination of optimal decalcification, fixation and sectioning techniques. Results in rabbit have produced good success as will be shown with histological images.

14 LONGITUDINAL CHANGES IN SPATIO-TEMPORAL PATTERNS OF EARLY ARM MOVEMENTS

Bhat A.[1], Heathcock J.[2], Lobo M.[2], Galloway J. C.[3]
Biomechanics and Movement Science, University of Delaware, Newark, DE19716

Introduction: Arm movements in the first months of infancy have been proposed to be important in the emergence of purposeful reaching. Moreover, an understanding of patterns of early arm movements can assist in early identification of movement deficits in atypically developing infants. Therefore, the aim of the present study was to determine the changes in spatio-temporal patterns of arm movements from 8 weeks to onset of reaching. Methods: 12 healthy infants were observed

in a cross sectional design with 4 infants at 8-9, 14-16, and 16-19 weeks of age. Infants in the oldest age group were consistently reaching for midline toys whereas the younger infants were non-reachers. At each session, we observed infant arm movements across two conditions a) without a toy and b) with a midline toy present. A six-camera Vicon motion analysis system recorded 3D positions and speeds of hand, shoulder, elbow and radioulnar joints. Dependent variables were a) Shoulder, elbow joint excursions and b) Shoulder, elbow joint speeds. Results: It was found that infants change their shoulder-elbow joint excursions as well as joint speeds between 8 and 19 weeks of age during spontaneous as well as toy-oriented arm movements. Conclusions: Results suggest that typically developing infants change their proximo-distal coordination as they transition from early flapping to reaching movements. Moreover, there are similarities as well as differences between the kinematics of spontaneous and purposeful arm movements. Implications: Our findings join other studies to suggest that there are important developmental continuities between spontaneous flapping and purposeful reaching. Future studies could utilize our results to understand early movement deficits of infants "at risk" for developmental delays.

15 THE EFFECT OF LATERALLY-WEDGED ORTHOSES ON GAIT AND FUNCTION IN PATIENTS WITH MEDIAL KNEE OSTEOARTHRITIS

Caitlin Cashen*, Emily S. Mika* and Irene S. Davis*^
*Dept of Physical Therapy, University of Delaware, ^Joyner Sportsmedicine Institute, Lexington, KY

Osteoarthritis (OA), defined as the degeneration of articular cartilage in joints, has become one of the leading causes of disablility in the elderly population. Pain and loss of function are often associated with the occurrence of OA. In-shoe orthoses are expected to indirectly realign the knee to help reduce pain and improve function. However, the mechanism for these changes is not completely understood. The purpose of this study was to assess the effect of in-shoe laterally-wedged orthoses on the knee mechanics and function of patients with medial knee osteoarthritis. It was hypothesized that peak knee adduction angle, adduction angle excursion and external knee adduction moments would decrease with the use of wedged orthoses, compared to neutral orthoses. It was also hypothesized that pain and physical function would improve. Ten subjects with a K-L grade of 2 to 4 medial knee OA were fitted with orthoses wedged from 5 to 15 degrees. Knee kinematics and kinetics were calculated following a motion analysis of each subject's walking gait in both a wedged and a neutral device. In addition, pain and function were assessed. Slight decreases in the external knee adduction moment and adduction angle excursion were observed in the wedged condition, compared to neutral. Knee adduction angle showed a trend towards increasing with wedged orthoses. A trend toward a decrease in pain and an increase in physical function was also observed in both the walking and stair climbing tests with the wedged versus the neutral condition. In conclusion, wedged orthoses tend to improve the walking mechanics, pain and function of patients with medial knee OA. With the addition of more patients these trends may become significant.

16 DEVELOPING AND TESTING OF AN EMG-DRIVEN MODEL TO ESTIMATE ANKLE MOMENTS AND MUSCLE FORCES

Shay Cohen, Kurt Manal and T.S. Buchanan
Center for Biomedical Engineering Research, Department of Mechanical Engineering

The ankle was modeled as one degree of freedom hinge, with four muscles: the Triceps Surae (TS) and the TIbialis Anterior (TA). A Hill-type muscle model was used to account for each muscle's force-length and force-velocity relations. Muscle activation from EMGs were claculated in two steps, taking into account a second order relationship, and nonlinear transformation from neural to muscle activation. Muscle tendon length and moment arm were calculated, using SIMM

software and its associated lower extremity model. EMG singnals were collected from 3 healthy subjects. The tasks included dynamometer isometric, isokinetic, in range of motion 5deg Dorsiflexion to 20deg Plantarflexion and gait. Muscles parameters as input to the model, were those used in SIMM as well as those we measured by Ultrasound (US) for each subject. Simulated anealling was used to calibrate the model (23 parameters, not include optimal fiber length and penneation angle), in which muscle parameters allowed to change within the physiological range. Average Model performance (RMS): Calibration Error=1.9 N-m, Prediction Error=9.5 N-m. Smaller Error (RMS) in calibration and prediction results achieved, when maximum muscle isometric force calibrated to much higher values then those in SIMM (e.g. 370% and 170% for TA and TS, respectively). Using the US measurements for the subject's muscle parameters, showed, on average, better calibration   and prediction results, compare to the results achieved using SIMM muscle parameters.This model will be used in future studies to exmaine ankle muscle comtribution to gait in patients with neuromuscular impairments (NIH grant R01 HD38582)

17 LATERALLY WEDGED INSOLES REDUCE KNEE PAIN DURING FUNCTIONAL ACTIVITIES IN SUBJECTS WITH MEDIAL KNEE OA

Stephanie Crenshaw, Todd Royer, Robert Butler, Irene Davis
Dept of Health, Nutrition, and Exercise Sciences and Dept of Physical Therapy, University of Delaware

The purpose of this study was to examine the effect of laterally wedged insoles on knee pain and function during a six minute walk test and a timed stair test. Sixteen people diagnosed with medial knee OA volunteered as subjects for this study. Subjects came to the lab twice for functional testing. On the first day (NW1), subjects performed a six minute walk and a timed stair test. Distance was recorded for the walk test and time was recorded for the stair test. Subjects also rated their pain on a 100mm visual-analog scale before and immediately after each test. Subjects were fitted for a laterally wedged insole and given approximately two weeks to accommodate to the insole. Subjects then came back to the lab to repeat the functional tests. This time the tests were performed in two conditions in a random order, with the wedged insole (W) and without the wedged insole (NW2). Two one-way ANOVA's with repeated measures indicated that there was no change in walking distance (500.8m, 519.8m, 525.9m) or stair time (14.4s, 15.3s, 14.6s) among the NW1, NW2 and W conditions. Two two-way ANOVA's indicated that knee pain was not significantly increased for the wedged condition for either of the functional tests. However, knee pain was increased for the two no-wedge conditions for both the stair test (42.1%) and the six-minute walk test (121%). These results indicate that short term accommodations to wedged insoles decrease knee pain during stair climbing and walking, however objective functional measures were unchanged.

18 LOWER EXTREMITY JOINT COUPLING AND PATELLOFEMORAL PAIN DURING RUNNING.

Tracy A. Dierks & Irene Davis
Dept. of Physical Therapy, University of Delaware.

Patellofemoral joint pain (PFP) is the most prevalent pathology in runners. Abnormalities in joint coupling have been suggested to be sources of running related injuries. However, few studies have examined joint coupling in an injured population. PURPOSE: To compare joint coupling in runners who have a history of PFP with those who do not using coupling methods of timing differences, continuous relative phase (CRP), and vector coding. METHODS: As part of an ongoing study, 13 females with a history of PFP were compared to 13 uninjured females. All were competitive runners (>20 miles/week) and uninjured at the time of data collection. Five trials of ground reaction force (GRF) data and kinematic data were collected during overground running at a speed of 3.65 ± 0.2 m/s. Various joint coupling relationships of rearfoot

eversion/inversion, tibial internal/external rotation, knee flexion/extension, and knee internal/external rotation were assessed with independent t-test at p<0.10. RESULTS: For all three coupling methods, differences were primarily observed in the tibial internal/external rotation with knee flexion/extension relationship, followed by the rearfoot eversion/inversion with knee flexion/extension relationship. In general, PFP runners displayed larger timing differences, as tibial internal rotation reached its peak earlier, suggesting asynchronous coupling. For the CRP, PFP runners tended to be more in-phase during early stance. However, PFP runners were more out-of-phase at midstance (50% of stance), where joint reversals typically occur. For vector coding, PFP subjects displayed less tibial internal rotation and less knee flexion relative to rearfoot eversion and knee internal rotation. CONCLUSION: These preliminary data suggest that runners with a history of PFP may exhibit differences in joint coupling when compared to uninjured runners.

19 USING A MATHEMATICAL MODEL TO PREDICT THE ISOMETRIC FORCE-INTENSITY RELATIONSHIP

Jun Ding[2], Trisha Kesar[1], Anthony S. Wexler[3], Stuart A. Binder-Macleod[1,2]
[1]Interdisciplinary Graduate Program in Biomechanics & Movement Science, Univ. of Delaware, Newark, Delaware 19716, [2]Dept. of Physical Therapy, Univ. of Delaware, Newark, Delaware 19716, [3]Dept. of Mechanical and Aeronautical Engineering, Univ. of California, Davis, CA 95616

Electrical stimulation of skeletal muscle can help patients with CNS damage to produce functional movements (FES). However, muscle fatigue limits the widespread clinical use of FES. To combat fatigue clinicians often increase stimulation frequency or intensity to maintain the required forces. Both accelerate the rate and level of fatigue. Because stimulation factors such as the activation pattern, frequency and intensity affect the force production and fatigue of the muscle, it is important to identify the optimal combination of these factors that produces the least fatigue for targeted force. We have previously reported the development of a force- and fatigue-model system that accurately predicts muscle forces prior to, during, and post fatigue testing of human muscles with a wide range of frequencies and stimulation patterns.This model aims to predict the changes in muscle forces when the stimulation intensity is modulated. The current model was developed and tested on quadriceps muscles (N=8) of healthy subjects at 65 degree knee flexion angles with stimulation trains of different patterns. The results showed that our model successfully predicted the forces produced when the muscle was activated with stimulation trains of a wide range of pulse widths (100-500us), frequencies (twitch~80Hz), and different pulse patterns.The success of the addition of an intensity component to our model system further supports the potential use of our model for the design of optimal stimulation patterns for individual users during functional electrical stimulation.

20 ON THE DESIGN OF GRAVITY BALANCED HUMAN LEGS USING PASSIVE ORTHOSES

Abbas Fattah, Ph.D., Sunil K. Agrawal, Ph.D., and Mark Deaver
Mechanical Systems Laboratory, Department of Mechanical Engineering,
University of Delaware, Newark, DE 19716, fattah, agrawal@me.udel.edu

People with severe muscle weakness from neurological injury, such as hemiparesis from stroke, often have substantial limitations.   The focus of rehabilitation after stroke is often on walking function, however, equipment available to facilitate walking function is severely limited. Most devices move patients through predetermined movements rather than allowing the patient to move under their control.
This paper presents the design of a gravity balancing rehabilitative robot to assist persons with both leg impairment to walk through elimination of the effects of gravity.

The design of the machine is based on a hybrid method for gravity balancing, with two steps: (i) locate the center of mass of a machine using auxiliary parallelograms; (ii) select springs to connect from the center of mass such that the total potential energy of the system is invariant with configuration. The design of the machine considers all motions of the leg and the pelvis by assuming the center of mass of pelvis to be located on the line joining the two hip joints. Preliminary version of this machine, with limited features, is being fabricated.

21 INVESTIGATING SENSOR TECHNOLOGIES TO MEASURE FINGER MOVEMENTS DURING PHYSICAL THERAPHY

John Fitzgibbons, Barbara Tuday, Dr. Glancey (UD), and Scott Davidson (ILC Dover).

Currently, when conducting hand rehabilitation sessions with patients, physical therapists must manually measure the angles at which patients can bend their fingers and wrist in order to evaluate their progress. There are approximately 41 angles in the hand and wrist that must be measured, making this a time consuming task. A device that would automatically measure these angles would be of great interest to therapists and patients. Currently, existing technology for such a device is either inaccurate or too costly. The goal of our project is to provide a device that would allow physical therapists and patients to perform their necessary measurements quickly, with high accuracy, but at a low cost. Since sensors will be used to evaluate motion, the team is focusing on developing a test methodology and test platform to investigate different sensor technologies. The test platform includes a test stand and data acquisition system and is used in conjunction with a methodology to measure tension, compression, torque, and bend radius. Thus far the data acquisition has been calibrated and tested for electric noise, applied movements and forces, and electrical connections. In terms of a sensor package the team is working with sensors that are either flexible in material or have incoporated mechanical joints. Also included in the sensor package is an electric connection which includes wires, solder joints, and crimps. One of the largest hurdles the team has faced is testing and securing the electical connection in an effort to eliminate the effects of external forces and movements on measurements. After characterization of the sensors the next step is to test them with external forces and movements similar to those of the hand and wrist. Finally, the sensors will be attached to a glove and calibrated.

22 IN-VITRO MEASUREMENT OF EXPIRATION FLOW IN THE UPPER RESPIRATORY AIRWAYS.

Frank Fresconi and Ajay Prasad
Department of Mechanical Engineering

This work investigates the fundamental flow in a converging bifurcation. When considered in the realm of physiological applications, this study can be used to assess the deposition of particles in the lung. Knowledge of the underlying airflow is required to develop an accurate dosimetry model to transport prescription drugs with precision into the bloodstream. Similarly, the harmful impact of pollutants on the respiratory system can only be assessed by first understanding the carrier airflow. Particle image velocimetry (PIV) and laser-induced fluorescence (LIF) experiments were conducted in a transparent model composed of three machined tubes mated together in a Y-shape. Measurements were taken in a plane containing the axes of the tubes and in the cross-sectional plane of the parent tube to elucidate flow patterns in the bifurcating passages of the human respiratory system. The primary objective is to determine the amount of secondary flow in a bifurcation during expiration. Results from novel experiments support past work and also show new features.

23 USING LOW COST FORCE SENSORS TO MEASURE ELBOW JOINT MOMENTS: TRADE-OFF BETWEEN COST AND ACCURACY

Joseph D. Gardinier, Kurt Manal
Center of Biomedical Engineering Research, University of Delaware

Musculoskeletal models have been used to estimate forces generated by individual muscles. To assess the ability of the model at predicting load, the model-estimated moment is compared to the joint moment recorded using a device known to be accurate. These devices are expensive, and generally a fixed or immoveable piece of laboratory equipment. An alternate low-cost, portable measurement device would be a useful tool if it could be used to measure joint moments within an acceptable level of error. The Purpose of this study is to examine and evaluate if low-cost force sensors are suitable for measuring isometric flexion and extension moments at the elbow. Our low-cost measurement system uses two flexi-force force transducers mounted to the medial and lateral inner surface of a subject specific custom molded wrist brace. The wrist brace is made from Thermoplast, and is calibrated from 0 to 90 lbs. A single subject fitted with the low-cost measurement device was secured to the mounting ring of a 6 degree-of-freedom load cell. This enabled force from both measurement systems to be recorded at the same time while the subject performed elbow flexion and extension efforts. For the purposes of this study, loads within ± 5% difference from the 6 degree-of-freedom load cell were considered acceptable. The accuracy and precision of the low-cost measurement system was less than the 6 degree-of-freedom load cell. Errors greater than 5% were noted at key times such as peak flexion and extension moment, and also at the onset of the load-directed efforts. The simplicity and portability of the low-cost measurement device is appealing. To increase the efficacy of the device as a reliable and valid research tool, the known error of the low-cost measurement device is taken into account when measuring joint moments at the elbow.

24 SINGLE AND DUAL MOTOR TASK COORDINATION DEVLOPMENT

Lauren Glime, Michelle Eichinger, MS, Sarah Trager, MS, & Nancy Getchell
University of Delaware Human Performance Laboratory, Department of Health, Nutrition and Exercise Sciences

The purpose of this study is to determine how typically developing children coordinate their limbs while performing simultaneous, multilimb tasks. As children develop, a trend exists towards increasingly stable and consistent performance of dual motor tasks within a self-determined frequency range (Getchell & Whitall, 2003). 60 participants in 5 age groups (4, 6, 8, 10, adult; 12 per group) performed 3 trials each of 2 single tasks (clapping, walking) and a dual task (clapping while walking). Measures of frequency (mean across trials), stability (mean standard deviation within trials) and consistency (mean standard deviation across trials) were compared using 5 X 2 X 2 (Age x limbs x task) ANOVAS. Frequency results indicated that significant main effects existed for age ($F = 18.57$, $p < .0001$) and limb ($F = 4.82$, $p < .029$) , and a significant interaction existed between age and limbs ($F = 2.79$, $p < .027$). Within-trial stability results indicated significant main effects for age ($F = 10.79$, $p < .0001$), limb ($F = 318.45$, $p < .0001$) and task ($F = 4.92$, $P < .028$), and significant interactions between age and limb ($F = 7.569$), $p < .0001$). Across-task consistency results indicated a significant main effect for age ($F = 12.19$, $p < .0000$) and limb ($F = 72.67$, $p < .0000$), as well as significant interactions between age and limb ($F = 3.87$, $p<.0046$) and age and task ($F = 2.63$, $p <.036$). Results suggest that there is a limb specific developmental trend towards decreasing frequency and increasing across trial consistency. A developmental trend towards increased within trial stability exist that is both limb-specific and task-specific. Portions of this research will be presented at NASPSPA 2004. This research was supported by the University of Delaware Research Foundation.

25 THE EFFECT OF INCREASING TOE-OUT ANGLE ON THE KNEE ADDUCTION MOMENT DURING WALKING AND STAIR CLIMBING IN HEALTHY PEOPLE

Mengtao Guo and Kurt Manal
Department of Mechanical Engineering

The external knee adduction moment is associated with the development and progression of medial compartment knee osteoarthritis (OA). It has been suggested that knee OA patients and healthy adults who walk with greater toe-out angle have a same first peak knee adduction moment during early stance and a lower second peak moment during late stance. In contrast, in the only study that controlled toe-out angle, the first peak adduction moment for teenagers was shown to increase during toe-out walking. This study did not control the walking speed, which is related to the magnitude of knee moment. To date, no study on this issue has controlled both toe-out angle and walking speed. In addition, although stair climbing is a more difficult task than walking for knee OA patients and the knee kinetics are different from those during walking, to date, no study has investigated the effect of toe-out angle on the knee adduction moment during stair climbing. Therefore, the purpose of this study is to examine the effect of increasing toe-out angle on the knee adduction moment in healthy adults during walking and stair climbing. In this study, walking and stair climbing with toe-out 30 degree was conducted by each of six subjects compared with the moment during self-selected gait (toe-out angle less than 10 degree). We found that increasing the toe-out angle increased the first peak knee adduction moment during walking and stair climbing, and it decreased the second peak knee adduction moment during walking but not during stair climbing. These results suggest that although toe-out gait reduces the second peak adduction moment, it has an opposite effect on the first peak moment, and therefore might be ill-advised for individuals with knee OA.

26 RELATIVE INTERLIMB KICKING FREQUENCY OF FULL-TERM AND PRETERM INFANTS IN THE MOBILE PARADIGM

Heathcock, JC, Bhat, AN, Lobo, MA, Gallloway, JC
Univeristy of Delaware Department of Physical Therapy

Background and Purpose: Preterm and fullterm infants show learning and memory differences during the mobile paradigm. Specifically, preterm infants show delays. In addition, preterm infants show differences from fullterm infants in their spontaneous kicking movements. The purpose of this project was to investigate the change in relative kicking frequency patterns of preterm and fullterm infants during learning and memory periods of the mobile paradigm. Subjects: Ten full-term infants and ten preterm infants were compared to a control group of ten full-term infants. Methods: The ratio of tethered leg kicks to total kicks was determined during the learning, short-term and long-term memory phases of the mobile paradigm Results: Initially, the kicking frequency of both legs was not different within the Full-term group, or Preterm group. Full-term infants increased the relative frequency of their tethered leg kicks during learning (p=0.014) and retained this pattern for 24 hours (p = 0.013). In contrast, preterm infants did not change the relative kick frequency of either leg during learning or memory phases, similar to Control infants. Discussion and Conclusion: Fullterm infants were independently able to adapt their kicking pattern in a more efficient manner to cause mobile movement, whereas Preterm infants did not. The inability of Preterm infants to adapt their leg movements to a task suggests an important early link between spontaneous kick patterns and the development of purposeful control of the legs. Specifically, prolonged intralimb coupling seen during spontaneous kicking in Preterm infants may affect the development of voluntary control. The mobile paradigm has the potential to provide simultaneous information regarding coordination as well as associative learning and memory in very young infants.

27 DEVICE TO SIMULATE HIP IMPACT DURING HUMAN FALLS

Richard M. Herseim, Undergraduate Honors Degree w/ Distinction Candidate in ME
James L. Glancey, Dept of ME
K. Samant, J. Trentacosta, W. Walker, Dupont

Falls are recognized as a significant threat to the health and well-being of the elderly. Several estimates indicate that over 10,000 people 65 and older die annually from fall-related injuries, making falls the leading cause of injury-related death for this age group. Hip fractures are among the most serious fall-related injuries. At present, no standard test or devices exists that can be used to simulate human falls, which makes research to understand the mechanics of falls very difficult. To address the need for a test method and protocol for studying falls, a project was initiated to develop a device that simulates human falls and the resulting hip-floor impact. The device is designed to approximate the kinematics and kinetics of a fall event, and is configured to accept full-scale physical models of the hip, femur, fat and tissue. Both fall height and effective body mass are adjustable and approximate a range of human heights and weights. Key outputs of the test device include the force vs. time profile exerted on the ball of the hip during impact with the floor, deformation of the hip model vs. time, and the velocity of the hip at impact. Other features of the device include a microprocessor-based controller for the automatic control of drop height, high frequency sampling during a fall event, and the automatic return of the hip model to the upright (start) position. Simulations and preliminary tests with the prototype configured for an average-sized person indicate the device is capable of accurately simulating a fall and the resulting hip-floor impact. Peak force exerted on the ball of the hip during impact is similar to values from simulations and to those reported from previous studies.

28 RELIABILITY OF EMG RECORDINGS USING AN ALTERNATIVE TEST OF MVIC

Wei-Li Hsu, MS, PT; Vijaya Krishnamoorthy, PhD, PT; John Scholz, PhD, PT
Department of Physical Therapy and Biomechanics & Movement Science Program

The value of an electromyogram (EMG) in the interpretation of normal and pathological movement depends on recording, processing, and normalization procedures. Traditional maximum voluntary isometric contraction (MVIC) of individual muscles/ muscle groups is the most common method used for EMG normalization. However, this method is a time consuming procedure despite constituting only a small portion of an experiment. This is particularly a problem when testing patients. The aim of the present study was to compare an alternative method of computing the MVIC, recording the maximum effort of several muscles simultaneously, to the traditional method. We investigated the within-day reliability of the method by studying the integrated EMG of 9 lower limb muscles during the alternative MVIC task. Five healthy subjects performed the traditional MVIC tasks separately for each muscle group as well as the alternative MVIC task in two testing sessions 2 hours apart. Amplitude analysis of the recorded surface EMG signals was performed for tibialis anterior, medial and lateral gastrocnemius, soleus, rectus femoris, vastus medialis and vastus lateralis, medial and lateral hamstrings. We determined the correspondence between the EMG values of the traditional and alternative MVIC tests by computing the relative percentage of the former obtained from the latter method. The intraclass correlation coefficients (ICC) of the alternative IEMGs were calculated to determine test-retest reliability. The method of computing maximum EMG from alternative MVIC test yielded values that were on average 96.7% ± 36.59% of the traditional value. Reliability (ICC= 0.753, single observer) of alternative IEMG values across sessions was found to be relatively high. Although some muscles had weaker correspondence than others, overall, the results suggest that the less time consuming alternative method of computing maximum EMG values used here provides a reasonable alternative when time and fatigue become issues, especially when testing different patient population

29 DEVELOPMENT OF DYNAMIC KNEE STABILITY

Terese L. Chmielewski, P.T., Ph.D., Wendy J. Hurd, P.T., M.S., Katherine S. Rudolph, P.T., Ph.D., Michael J. Axe, M.D., Lynn Snyder-Mackler, P.T., Sc.D., FAPTA
Department of Physical Therapy

Clinical progression following anterior cruciate ligament (ACL) injury is variable.   Following ACL injury, most individuals experience significant decreases in their activities of daily living and sporting participation secondary to functional knee instability (non-copers).   A select sub-population is able to maintain functional knee stability through the implementation of dynamic knee stabilization strategies and return to pre-injury activity levels following ACL injury without surgical intervention (copers); these individuals who have potential to develop successful stabilization strategies may be identified early after injury through a screening process (potential copers). The purpose of this study was to compare kinetic and kinematic patterns between potential copers and matched uninjured subjects before and after participation in perturbation training. Motion and electromyography (EMG) data were collected (vastus lateralis [VL], medial [MH] and lateral [LH] hamstrings, and medial gastrocnemius [MG]) from 16 injured and 16 uninjured subjects during normal and disturbed walking. Before training, potential copers had significantly higher VL-LH and VL-MG co-contraction compared to uninjured subjects ($p<0.10$) and reduced peak knee flexion angles ($p<0.05$). After training potential copers demonstrated movement patterns that more closely simulated those of uninjured subjects: reduced co-contraction indices and increased peak knee flexion angles. Normalized co-contraction in potential copers post-training suggests that the program alters muscle activation to provide dynamic knee stability.

30 ULTRASOUND CONTRAST AGENTS: EXPERIMENTS AND MODELING

Pankaj Jain, Dhiman Chatterjee and Kausik Sarkar
Department of Mechanical Engineering, University of Delaware, Newark, DE 19716.

Encapsulated micron-sized gas bubbles are used in medical ultrasound to enhance the image contrast. The encapsulation (made of protein, lipid or surfactant) plays an important role in the dynamics of these microbubble contrast agents. Characterization of these agents involves identifying the role of encapsulation through suitable modeling and experiments. In this work, we characterize ultrasound contrast agents through modeling of the interface and in-vitro attenuation and scattering experiments. Encapsulation is modeled as an interface between inside gas and outside liquid with dilatational viscosity and interfacial tension as interfacial rheological parameters. The rationale for the zero-thickness interface lies in the anisotropy in the structure of the encapsulation. Small-amplitude in-vitro attenuation experiments are performed, and linearized theory is used to determine these surface parameters. The model was investigated for its ability to predict the nonlinear response. Predictions from the model are compared to scattering obtained from experiments performed with different pressure amplitudes and frequencies. We have applied our model on different contrast agents like Albunex, Optison, Sonazoid, and Quantison. We will present our experimental results; discuss characterization and the subsequent validation.

31 MANUFACTURING AND PERFORMANCE OF CARBON NANOTUBE/HIGH DENSITY POLYETHYLENE COMPOSITES

Brian B. Johnson, Michael H. Santare, John E. Novotny, Suresh G. Advani
Department of Mechanical Engineering and Center for Composite Materials
University of Delaware, Newark, DE 19716 (santare@me.udel.edu)

This study describes the manufacturing of Carbon Nanotube/High Density Polyethylene composites (CNT/HDPE) and the testing of these materials to determine several key material characteristics (i.e. stiffness, tensile strength, work-to-failure and wear resistance). These nanocomposites are made from untreated, multiwalled carbon nanotubes and HDPE through a process of mixing and extruding. Materials were created with varying weight percentages of nanotubes (0%, 1%, 3%, and 5%) and then molded and machined to form standard test specimens for small punch testing and block-on-ring wear testing. Mechanical tests were then conducted for the various volume percentages of nanotube content with pure HDPE as the control. It was found that each of the measured mechanical properties of the composite increased as a function of increased nanotube content in the range studied.

32 EFFECTS OF FREQUENCY AND INTENSITY MODULATION ON FATIGABILITY OF SKELETAL MUSCLE DURING ELECTRICAL STIMULATION.

Trisha Kesar, Li Wei Chou, Stuart Binder-Macleod
BMSC Graduate Program, University of Delaware

Functional electrical stimulation (FES) uses electrical stimulation to generate functional movements in weak or paralyzed muscles. The central nervous system (CNS) uses both recruitment (varying the active motor units) and rate coding (varying the firing frequency of motor units) to achieve a precise control of muscular force. Similar processes of varying the level of recruitment (through intensity-modulation), and rate-coding (through frequency-modulation) are used during electrically elicited contractions. Interestingly, although the CNS appears to use different strategies of combining these two processes to control different muscles, there is no theoretical model to suggest the optimal strategy for combining these two processes during either volitional or electrical contractions. This study is the first step towards determining an 'optimal' modulation strategy for controlling muscle force output during electrical stimulation. The goal of this study is to compare the fatigue and forces produced by electrically induced isometric contractions of the human quadriceps muscle in response to a frequency-modulation protocol, an intensity-modulation protocol, and 3 control protocols without modulation (20, 33 and 60 Hz). For the modulation protocols, either the stimulation frequency or the intensity (pulse duration) will be increased stepwise at regular intervals, keeping the other stimulation parameters (number of trains in the protocol, train-duration, rest time, initial force) constant. The dependant variables for each protocol will include the peak force at the 60th, 120th and 180th contractions; sum of forces over the first, middle, and last 60 contractions; and the percentage force decline from 1st to the 180th contraction. Preliminary results suggest that intensity-modulation may produce higher peak forces compared to the other protocols. The results of this study will enhance our understanding of the effects of modulation of frequency and intensity during electrical stimulation, and will help us design future studies that combine the two strategies.

33 AN INVERSE ANALYSIS OF ARTICULAR CARTILAGE IN UNCONFINED COMPRESSION

F. Lei and A.Z. Szeri
Department of Mechanical Engineering

The last two and a half decades witnessed the emergence of a number of cartilage models, with the specific aim of estimating the mechanical properties of articular cartilage and predicting its response to external loading. Most of these models naturally classify into one of two groups, models employing the theory of mixtures and those relying on poroelastic theory. Most current models can simulate articular cartilage to some extent. How well is such simulation executed by a particular model relative to its own limitations depends on the choice of the numerical values of the parameters essential to that model. Since parameter selection is done by trial and error by most model builders, the process is highly subjective; it becomes difficult to assess which model

performs best. To aid further development of cartilage modeling, there is a need for an objective, scientific method to assess and contrast the different models under particular loading protocols. The present paper describes a procedure for estimating the numerical values of the parameters of a particular model, which will provide best fit to specified load-displacement histories, when employed in that model. In the procedure, a three-dimensional fibril-reinforced poroelastic finite element model, based on ABAQUS, is coupled with a nonlinear least square routine in MATLAB. To illustrate the performance of our optimization process, we perform optimization of from one to six parameters. The computational results show that the optimization procedure gives a unique set of model parameters in all cases tested.

34 MODELING OF ARTICULAR CARTILAGE BY FIBRIL-REINFORCED POROELASTIC MODEL

F. Lei and A. Z. Szeri
Department of Mechanical Engineering

Articular cartilage exhibits complex behavior and properties, including visco-elasticity, anisotropy, and inhomogeneity and tension-compression nonlinearity (TCN). The cartilage is a multiphase material composed of porous matrix saturated with water and ions, reinforced by fibril network. The apparent nonlinear viscoelastic behavior is due to an intricate interaction of the matrix and the interstitial fluid. Current knowledge about cartilage modeling is incomplete. The biphasic or triphasic theories developed by Mow and coworkers cannot successfully simulate the different experimental conditions with the same set of model parameter values. This shortcoming of 'conventional' mixture-theory based models is probably due to an absence of fibrils that are the major reason for TCN. The fibril-reinforced model proposed by Soulhat seems reasonable to explain TCN, but the fibril distribution in radial and circumferential directions is questionable; the cartilage obviously exhibits an orthotropic symmetry according to experimental results. Furthermore, the observed phenomena of strain softening followed by strain hardening in compression are not well explained by this model. We propose a comprehensive 3D fibril-reinforced poroelastic model incorporating the swelling pressure, which can assist in explaining the above-mentioned complex behavior. In this poster, we outline the mathematical development of the model and discuss its implementation in the FE software ABAQUS. The coordinate system is defined by the split-line (1-direction), the direction perpendicular to the split-line in a plane tangent to surface (2-direction), and the direction normal to this plane (3-direction). To demonstrate the accuracy of our numerical model, we compare its output with both analytical solutions and published numerical results. Curve fitting the model to experimental data needs to be further investigated.

35 GENERAL AND TASK-RELATED EXPERIENCES AFFECT EARLY OBJECT INTERACTION

Michele A. Lobo & James C. Galloway
The University of Delaware
Geert J.P. Savelsbergh
Vrije Universiteit & Manchester Metropolitan University

The purpose of this study was to determine the effects of two types of experiences on the emergence of infants' abilities to interact with objects using the hands and feet. We offered thirty 8- to 12- week-old infants toys at their hands and feet while observing them with standard video and a high-speed motion analysis system at the start and end of 2 weeks. Between visits, infants received no enhanced movement experience (NE), general movement experience (GE), or task-related movement experience (RE). Both GE and RE infants were more successful at contacting toys at visit 2 using their hands than were NE infants ($p = .000$, $p = .000$ respectively). RE infants had more frequent hand-toy contacts than GE infants ($p = .000$). In contrast, only GE infants had more frequent foot-toy contacts than NE infants ($p = .01$). Similar group differences were seen for other measures of object interaction ability, such as ability to move closer to the toy. Thus, the

same experiences resulted in differential effects depending on which limbs the infant used to interact with objects. These results suggest that different movement experiences can lead to advancements in infants' earliest object interactions. They also highlight the idea that even early purposeful behaviors result from a complex interplay of experience, current ability, and task demands.

36 DEVELOPMENT OF A STANDARD TEST METHODOLOGY FOR HAND-HELD POWER TOOLS TO ASSESS HAND-ARM VIBRATION CHARACTERISTICS

J. Moore, J. Lawrence, and J. Glancey
University of Delaware

Power tools that transmit high frequency vibration to the hand and arm continue to be used throughout the construction and mantainence industries. However, long-term exposure to vibration has been a leading cause in ergonomic injuries such as Vibration White Finger, Hand and Arm Vibration Syndrome, Carpel Tunnel and Hearing Loss. The eventual goal of this research is to decrease the risk of such injuries by developing safer power tools that not only isolate and reduce the vibration but also eliminate the high frequencies that cause hearing damage. However, no current testing methods exist that do not require humans to operate the tools during an experiment. As a result, the first objective of this project includes developing an effective, repeatable means of evaluating hand operated power tools with human test subjects. Subsequent goals using this new testing procedure include characterizing existing impact tool performance and developing new concepts to reduce hand-arm transmitted vibration. Currently, a new test stand and standard testing methodology have been developed and qualified. This technque utilizes mutiple sensor to measure both sound and vibration characteristics, and does not require a human to operate the tool. Research has been conducted to evaluate commercially available tools and products marketed as vibration reducing, and the results indicated significant hand vibration still exists. New designs for vibration reduction have been developed and are currently being tested.

37 EVALUATION OF THE HAND-ARM VIBRATION CHARACTERISTICS OF NEW HAND-STRUCK TOOL DESIGNS USING HIGH PERFORMANCE ENGINEERING POLYMERS

Daniel R. Muhlenforth, Dominic Schiavoni, and James Glancey

The use of hand-struck tools is still a necessary job function for technicians in several industries throughout the world. Despite the importance of these tools, growing concerns regarding the detrimental effects of their long-term use continue to grow. Several studies have already demonstrated a link between vibration from tools and various injuries including vibration induced white finger, hearing loss, and Hand-Arm-Vibration Syndrome. Our current research is focusing on the effectiveness of various engineering polymer materials and new tool designs the can potentially reduce transmitted vibration. With the use of multiple accelerometers mounted on the hand and tool, the levels of vibration being transmitted in the x, y, and z directions at the moment of impact were measured. All tests are being conducted in accordance with the ISO standards to insure a safe, valid, and accurate analysis. Results thus far have proven that the integration of engineering polymers (as an alternative to tradtional metals) into tool designs can significantly reduce the hand-arm vibrations being transmitted from the tool. These results validate other on-going research to develop FEA models to predict tool vibration characterisitcs.

38 THE EFFECTS OF AGE AND REFERENCE CONDITION ON PHASE LOCKING AND PHASE ERROR IN A DUAL MOTOR TASK

Priya Pabreja, BPT and Nancy Getchell, PhD
University of Delaware

The accomplishment of multilimb tasks relies on the ability to couple or decouple limbs in a flexible yet consistent manner. What is the developmental time course in the ability to voluntarily couple all four limbs? and how does this ability differ in self-referenced versus auditory referenced coupling? 4, 6, 8, 10 year old and adult groups (12 participants per group) performed a dual motor task (simultaneously walking and clapping) in 4 conditions. Condition 1 had no a priori coupling requirements; in condition 2, participants were asked to couple their clap to their step. Condition 3 and 4 involved coupling the clap and step together with a metronome beat at either preferred clap or step frequency. Phase error (the difference between target and actual phasing) and phase locking (phase stability within a trial) were calculated. There were developmental and condition specific differences for phase error; a 5 x 4 ANOVA with repeated measures indicated significant main effects for age ($F_{(4, 56)} = 2.62$, $p<.036$) and task ($F_{(3, 57)} = 6.04$, $p<.001$). Further, there were developmental differences in phase locking within trials, revealed by a significant main effect for age ($F_{(4, 57)}=20.34$, $p<.0001$). Condition specific phase locking was indicated by a significant main effect for task ($F_{(2, 58)}=8.80$, $p<.0001$). When looking across trials, there was a trend towards greater consistency in phase locking. These results suggest that there is a developmental trajectory towards consistency and location of phase locking and in phase error. The metronome condition referenced to step frequency had little phase error and tight phase locking. Self-referenced absolute coordination had tight phase locking, while at the same time had the highest amount of phase error. Results are discussed within a dynamic pattern framework. This research was supported by the University of Delaware Research Foundation.

39 MORPHOLOGICAL AND NEURAL CONTRIBUTIONS TO CHANGES IN QUADRICEPS STRENGTH AFTER TOTAL KNEE ARTHROPLASTY

*Mizner RL; **Stevens JE; *Petterson SC; **Vandenborne K; *Snyder-Mackler L; *University of Delaware, Newark, DE. **University of Florida, Gainesville, FL.

INTRODUCTION: While TKA reduces pain and improves knee range of motion, reductions in quadriceps strength and functional capacity may still be present at one year. Strength declines as high as 40-60% one month after TKA have been reported in the literature. The purpose of this study was to assess the relative contributions of arthrogenous muscle inhibition (AMI) and muscle atrophy to quadriceps strength one month after TKA. METHODS: Seven patients with unilateral, end-stage knee OA were tested 10 days before and 28 days after primary TKA. Quadriceps strength (MVIC) and AMI were measured using a burst-superimposition technique. Quadriceps maximal cross sectional area (MCSA) was assessed utilizing MRI. The influence of knee pain on AMI and the contribution of AMI and atrophy to MVIC was analyzed using linear regression. Differences in average quadriceps strength, AMI, and MCSA were compared using paired t-tests. RESULTS: Involved quadriceps were significantly weaker (17%) despite the same levels of AMI compared to the uninvolved limb prior to TKA. MVIC decreased by 62%, AMI increased by 17%, and MCSA decreased by 12% compared to preoperative values. Changes in AMI accounted for the majority of the variability in the change in MVIC ($r2=0.67$), whereas atrophy ($r2=0.214$) nor knee pain during MVIC ($r2=0.118$) contributed significantly. Collectively, AMI and atrophy explained 82% of variance in loss of quadriceps strength ($R2=0.820$). DISCUSSION: While atrophy accounts for 20% of the strength loss after TKA, AMI appears to be the predominant factor. Implementation and use of intense exercise regimens, electrical stimulation, and biofeedback may help to improve strength outcomes and shorten rehabilitation after TKA by facilitating strong muscular contractions and muscle activation.

40 REFLEXIVE MUSCLE RESPONSES DURING VALGUS PERTURBATIONS AFTER ANATOMIC TIBIOFEMORAL REALIGNMENT

Ramsey DK, Lewek M, Rudolph KS, Snyder-Mackler L.
Department of Physical Therapy

Introduction: We examined whether patients with medial compartment knee osteoarthritis (MKOA) altered their reflexive muscle responses to a rapid valgus perturbation following anatomic tibial realignment. Methods: Nine subjects, with MKOA and genu varum were tested prior to (PRE) and one year (POP) following Opening Wedge-High Tibial Osteotomy (OW-HTO). Nine healthy subjects (NORM) were compared. Knee alignment, joint laxity and quadriceps strength were measured. Muscle reflexes, joint kinematics and kinetics were measured in response to a rapid valgus perturbation in standing. Electromyographic activity of six lower extremity muscles was assessed before, during, and after plate movement. Co-contraction indices were determined during a 40-175msec window following plate movement, which is consistent with the long loop reflexive response. Paired t-tests were used to compare PRE and POP data and independent samples t-test were used to compare the MKOA and NORM groups. Significance was set at $p < 0.05$. Results: Post operatively, medial laxity was significantly lower (p=0.02) but comparable to the NORM group (p=0.394). Both PRE (p=0.013) and POP (p=0.005) quadriceps strength were significantly lower than controls. During the long loop interval there was a trend towards higher VLLH co-contraction postoperatively (p = .092) whereas during the volitional activation interval, co-activations were reduced for both VMMH (p=0.073) and VMMG (p = .009). For all groups, quadriceps strength correlated with nearly all co-contraciton during the long loop interval. Discussion: The OW-HTO realignment procedure reduced the medial laxity, however substantial quadriceps weakness persisted and the reflexive muscle activation strategy may be detrimental to the joint over time. The reduced volitional medial co-contractions after surgery indicate a stabilization strategy that would preserve joint integrity over time. However, the high co-contractions observed during the long loop interval suggest the strategy has not been incorporated into subconscious control of the knee.

41 CORRELATION BETWEEN EMG AND PENNATION ANGLE AS DETERMINED USING ULTRASOUND

Dustyn P. Roberts, Kurt Manal and Thomas S. Buchanan
Center for Biomedical Engineering Research, Department of Mechanical Engineering

The angle that muscle fibers insert into tendon in pennate skeletal muscles is an important determinate of the muscle's functional characteristics. Pennate muscles allow more fibers to align in parallel, increasing the contractile force potential compared to a muscle of identical composition and volume with longitudinal fibers. Consequently, the pennation angle is an important parameter in musculoskeletal modeling when predicting musculotendon length, force generation, and contribution to joint moment. Historically, pennation angles were measured post mortem using cadaver muscles and any changes in the angle during contraction were considered negligible. However, ultrasonography has recently been used as a tool to measure pennation angle in vivo and significant changes in pennation angle between rest and isometric maximum voluntary contraction as measured through electromyography (EMG) and dynamometry have been documented for several muscles. Other studies have shown pennation angle of specific muscles to vary significantly with age, gender, repeated muscle contractions, muscle hypertrophy, and atrophy/disuse. Clearly, incorporating changes in pennation angle into any musculoskeletal model will therefore increase anatomical and physiological accuracy. However, a relationship between pennation angle and muscle contraction must first be determined in vivo to be practical and applicable to modeling. This study will use electromyography and dynamometry to measure muscle activity and external joint moment while simultaneously imaging the muscle

using ultrasonography during graded isometric contractions to measure fiber pennation angle. The goal is to establish predictive relationships between pennation angle, moment, and EMG in healthy subjects as well as subjects with unilateral lower limb injuries.

42 KNEE STABILITY IN PATIENTS WITH MEDIAL KNEE OA

Schmitt LC, Rudolph KS
Dept of Physical Therapy and Biomechanics and Movement Sciences Program, University of Delaware

Tibiofemoral joint OA is responsible for more chronic disability than any other medical condition (Bulkwalter, 2000) and many factors are associated with its development. Knee laxity and ensuing instability appear to contribute to altered movement and muscle activation patterns that are associated with progression of OA (Lewek, 2003). Patients with medial knee OA and varus alignment demonstrate altered neuromuscular responses in response to standing valgus perturbations at the knee (Lewek, 2003). Greater co-contraction of medial knee muscles may represent an attempt to compensate for increased medial knee laxity (Lewek, 2003). We will be imposing a destabilizing event during walking to determine if similar stabilization strategies are used by patients with medial knee OA. Understanding the interactions between knee laxity, joint instability, skeletal alignment and weakness are essential before appropriate rehabilitation and training paradigms can be developed to halt or slow the progression of this disabling condition. Subjects will include patients with diagnosed unilateral medial knee OA (various grades) and uninjured control subjects. We will make comparisons between the involved limbs of patients to their uninvolved limb and to the control subjects matched by age and BMI. We will assess quadriceps muscles force output and activation, reports of knee instability, amount of knee laxity, and movement and muscle activation patterns during walking. Knee stabilization strategies at the knee will be assessed with a plate that translates laterally with the subject in quiet standing and during free speed walking. In this presentation of our work in progress, we will discuss our hypotheses, specific methodolgy and present pilot data collected from three individuals.

43 SUBJECT-SPECIFIC LOWER EXTREMITY MUSCLE MORPHOLOGY EVALUATED FROM MAGNETIC RESONANCE IMAGING

Christine Marie Tate*, Glenn N. Williams^, Peter J. Barrance*, Thomas S. Buchanan* *Center for Biomedical Engineering Research, Department of Mechanical Engineering, University of Delaware; ^Graduate Program in Physical Therapy and Rehabilitation Science, University of Iowa; UD BIOMS program Ph. D. graduate, 2004

Purpose: To determine muscle volumes and cross sectional areas (CSAs) of lower extremity muscles of athletes and compare these with previously reported values. Next, to determine if both legs could be represented by measurements from only one side, we examined dominant/non-dominant differences in muscle volumes and CSAs. Methods: Axial spin-echo T1-weighted MR images were obtained from the level of the ankle mortise to the iliac crest in 10 athletes (age 18.8 ± 3.7 yrs). Each subject's three-dimensional anatomy was digitally reconstructed from the MR images. Muscle volume and peak CSA were then calculated for 13 muscles. One-way ANOVAs were used to compare values with those reported in literature and paired t-tests were used to compare left to right differences. Results: The mean volume and CSA of each quadriceps muscle in this study of athletes were significantly different ($p<.005$) from previously reported values from studies of non-athletes. The ratio of total quadriceps to total hamstrings volume averaged nearly 3:1 (2.90 +- .24), whereas previous studies reported values closer to 2:1 (2.06 +- .17) (Friederich and Brand). . There were also significant differences in the ratios of individual muscles to total muscle groups. Significant left to right differences were observed for the vastus lateralis, vastus medialis, biceps femoris short head, semimembranosus, and medial gastrocnemius. Conclusion: The muscle morphology of young athletes is different

from previously reported values in the literature. This new set of data will serve as an important reference for research and biomechanical modeling.

44 THE EFFECT OF WORKSPACE ON THE USE OF MOTOR ABUNDANCE

Ya-weng Tseng, MS, PT; John P. Scholz, PhD, PT
Department of Physical Therapy

Previous studies have shown that the nervous system makes use of motor abundance in the control of reaching and pointing (Tseng et al. 2002). Specifically, goal-equivalent variations of joint combinations are utilized while variations in joint combinations that would lead to performance variability are restricted. Because pervious work examined only a limited region of available workspace, the present study examined the extent to which this coordination strategy generalizes to a broader region of the available workspace. The Uncontrolled Manifold approach was used to examine the effect of workspace location on the use of motor abundance to control the hand's path during reaching. Subjects pointed to targets located in the contralateral and ipsilateral workspaces at two different distances. The coordination of ten joint angles of the right arm, including scapula motions, was analyzed. The variance of joint configurations consistent with a stable hand path across trials was significantly higher than joint configuration variance leading to an inconsistent hand path for reaching to all parts of the workspace. The relative difference between these two variance components was affected by target direction to a greater extent than target distance. The control of hand path direction when reaching in the ipsilateral workspace was associated with greater selective use of motor abundance compared to reaching in the contralateral workspace. Control of hand path extent was not affected by target direction. Biomechanical factors, such as the ability to coordinate limb movement with interactive torque and the anisotropy of arm inertia are discussed as possible reasons that lead to the observed workspace effects.

45 MECHANCIAL CHARACTERIZATION OF A CARTILAGE TISSUE EQUIVALENT DURING ITS DEVELOPEMENT

Turka, Christina M., Novotny, John E., Dodge, George R.
Department of Mechanical Engineering & A.I Du Pont Children's Hospital

Articular cartilage is an avascular tissue that irreversibly degenerates during osteoarthritis. One active field of study is to develop a cartilage-like biomaterial that may be used as replacement cartilage. We are performing mechanical testing on a cartilage tissue equivalent (CTE) from neonatal porcine chondrocytes that have been grown in a suspension culture. Specimens were tested at ages 8 and 16 weeks. Seventeen specimens were formed by removing a 5 mm cylindrical plug from the CTE. These specimens were placed in a confined compression chamber bathed in phosphate buffer solution. One dimensional incremental stress-relaxation was performed using a materials testing machine and a porous platen. Initial thickness of the specimen was obtained by applying a tare load of 0.03 N for 5 minutes prior to testing. The test involved an initial tare load of 0.8 N applied for 15 minutes followed by five 7.5% compressive stain steps at a rate of 2.5 N/m-s followed by a 1400 sec hold. This holding time allowed the stress response to equilibrate before the following step occurred. The equilibrium stresses and stretches were determined from the response and fitted to a non-linear hyperelastic equation based on the biphasic model to determine the aggregate modulus, Hao. Then the aggregate modulus along with the experimental data was curvefitted to a non-linear model using a numerical method to obtain the permeability, ko, of the CTE. The results of the eight week specimens involve a Hao of 0.0416 +/- 0.0043 MPa and a ko of 2.846E-13 +/- 2.48E-13 m4/Ns. The sixteen week specimens had a Hao of 0.0352 +/- 0.0076 MPa and a ko of 2.673E-13 +/- 1.063E-13 m4/Ns. The tissue mechanical properties compare favorably with other tissue engineered

materials, and hopes are to optimize mechanical and biological factors during culture to reach those of native cartilage.

46 THE ROLE OF LUMBOPELVIC STRENGTH IN LOWER EXTREMITY INJURY PREVENTION AND OVERALL ATHLETIC PERFORMANCE: GENDER DIFFERENCES

John Wilson and Irene Davis
Department of Physical Therapy and Biomechanics & Movement Science Program

Lumbopelvic or core strength may play a role in lower extremity injury prevention and overall athletic performance. Females may exhibit decreased strength in these muscle groups. PURPOSE: 1) to compare hip and knee torque between males and females and 2) to describe the relationship between these strength measures and tibiofemoral valgus (TFV) angle and single leg (SL) hop for distance. METHODS: 24 males and 22 females were evaluated for peak isometric trunk flexion and extension, side bridging, hip abduction and external rotation (ER), and knee flexion and extension torque using hand-held dynamometers and strap stabilization. Digital images were recorded during SL stance and SL squats to 45° knee flexion to determine TFV angle. SL hop for distance was recorded for the dominant leg and normalized to body height. All variables were compared across gender using an ANOVA (α = 0.05). Linear regression analysis was used to examine the relationship of core strength measures to TFV angles and SL hop scores. RESULTS: Females demonstrated significantly lower core torque measurements than males for all muscle groups except trunk extension. Females displayed significantly greater TFV during single leg stance (p= 0.02) and single leg squats (p= 0.02) and a greater tendency to move into valgus knee alignment positions than males (p < 0.01). Females also jumped significantly shorter distances than males (p= 0.04). Hip ER torque most significantly predicted TFV angle (p= 0.17), and trunk flexion and extension strength most significantly predicted SL hop distance (p= 0.01). DISCUSSION: Core strength may influence lower extremity alignment and performance during athletic tests. Strength differences between males and females may contribute to the etiology of the gender bias for specific lower extremity injuries in female athletes. CONCLUSION: Females demonstrated significantly lower hip and knee torque, greater TFV during SL squats, and shorter SL hop for distance scores. Additional subjects may strengthen the relationship between these variables.

47 EXPERIMENTAL MEASUREMENT OF PARTICLE DIFFUSION AND THREE DIMENSIONAL STRAIN FIELD IN ARTICULAR CARTILAGE UNDER STATIC COMPRESSION

Gregory Wolos, John E. Novotny
Department of Mechanical Engineering, University of Delaware, Newark, DE 19716

The mechanical properties of articular cartilage vary with depth from the joint surface. To fully characterize the anisotropic properties of cartilage, the tissue must be observed on a cellular scale. A custom mechanical testing device was manufactured to perform unconfined compression experiments on the stage of a Zeiss multi-photon confocal microscope. The device utilizes a very high resolution stepper motor and linear slide to control the compression of cartilage on murine humeral heads. As the specimen is compressed, the multi-photon microscope collects three dimensional images of the chondrocyte nuclei and inert Dextran particles in the extracellular matrix of the cartilage. Once reconstructed, the images can be used to track the movement of cell nuclei to determine the strain field in the cartilage matrix.   In addition, fluorescent recovery after photo bleaching (FRAP) experiments were performed to calculate the two dimensional diffusion coefficient of 10 kDa Dextran particles as a function of cartilage loading. Since cartilage is avascular, diffusion is the primary method of particle transport in the extracellular matrix. Changes in diffusion rates may affect the transport of nutrients, matrix molecules, and cell signaling. Diffusion rates will be compared at different depths within the cartilage and under different static loads.

48 FLOW-DEPENDENT NEUTRAL SOLUTE TRANSPORT IN CARTILAGE

L. Zhang and A.Z. Szeri
Department of Mechanical Engineering, University of Delaware

The chondrocytes of a cartilage tissue receive nutrients and macromolecules across the articular surface solely by diffusive and/or convective transport. Consequently, a detailed understanding of solute transport processes within the cartilage, and the ways mechanical loading may influence these processes, is essential to the understanding of cartilage physiology and cell biological response to external loading. The objective of the current study is to examine what influence, if any, does matrix structure, size of the diffusing molecules, and mechanical loading, have on transport processes, and to investigate the circumstances that enhance transport of a neutral solute. A 3-D finite element formulation, based on incompressible mixture theory, is derived for this purpose. In implementing this model in the finite element code Abaqus, we recognize that change in solute concentration due to diffusion is analogous to change in temperature in the presence of fluid motion. Solute transport through the lateral surface of a cylindrical sample loaded in unconfined compression, and through the top surface of a cylindrical sample loaded in confined compression, is investigated. Both static loading and dynamic loading are applied, and the diffusion coefficient is allowed to depend on strain.

49 ANALYSIS OF ROTATOR CUFF TEARS USING CINE-PHASE CONTRAST MRI

Hehe Zhou and John Novotny
Department of Mechanical Engineering

Rotator cuff (RTC) tears are a common pathology of shoulder joint. Imaging modalities are important tools of diagnosis, however there are controversies related to their uses. This may be due to the fact that the tendon tear may be indistinguishable without retraction. Cine Phase Contrast MRI (CPC-MRI) has been proved to be an efficient non-invasive means to investigate the dynamics of heart (van Dijk, 1984) and the kinematics of human joint system (Sheehan et al., 1998) quantitatively. It can describe anatomical information as well as the velocities of the object performing a cyclic motion. The whole motion course is interpolated into specific time frames or steps. With suitable algorithms (Pelc et al., 1994; Zhu et al., 1996), trajectories of region of interest (ROI) can be derived from the velocity field collected by CPC-MRI. This study proposes to apply CPC-MRI (Fig. 1) to investigate the mechanics within the supraspinatus muscle. This dynamic method could determine abnormities within the supraspinatus with tears compared to the normal ones. CPC-MRI may offer a better way to observe and understand the RTC function, diagnosis RTC tears and follow post-operative repair status and rehabilitation methods.

50 GENDER DIFFERENCES IN ARCH HEIGHT

Rebecca Avrin Zifchock[1] and Irene Davis[1,2]
[1]Motion Analysis Laboratory [2]Joyner Sportsmedicine Institute

Introduction: One common way to categorize the foot is using arch structure. To date, there are no studies examining the difference in arch structure between males and females. Understanding such differences could lend insight as to why injury biases exist. Therefore, the purpose of this study is to identify whether there is a significant difference in the arch height between genders. It was hypothesized that females would have lower arches. Methods: Ninety-five subjects, 44 male and 51 female, between the ages of 18 and 65 gave consent to participate in this study. Portable platforms that raised the subject's feet 19mm off the floor were positioned

to support each foot under the heel and metatarsal heads only. This eliminated the "floor effect" and allowed the arch to drop as much as the foot anatomy permitted. Total foot length and truncated foot length (the most posterior point on the foot to the 1st metatarsal head) was measured while seated. Dorsum height at ½ total foot length was measured while seated and standing. The arch height index (AHI), as described by Williams, et al. (Williams et al., 2000) was used to obtain a normalized value of arch height, in a dimensionless unit we call AHI units, for comparison between subjects: AHI = dorsum height/truncated foot length. All comparisons were made using the data obtained for the dominant foot. Statistical comparisons between males and females were made using two independent t-tests: (1) male vs. female standing AHI and (2) male vs. female seated AHI. Analyses were performed at $\alpha = 0.05$. Results: AHI was not different between genders in either the seated or standing conditions. This result is suprising given previous literature which reports increased knee valgus and ligament laxity, both of which would predispose females to more everted, flatter arches.

Attendees

Agrawal, Abhishek	Gregor, Robert J.	Perumal, Ramu
Agrawal, Sunil	Guo, Mengtao	Peterson, Stephanie, C.
Alicknavitch, Michael	Gustavsen, Geoffrey	Prasad, Ajay, K.
Banala, Sai	Heathcock, Jill, C	Ramsey, Dan, K
Barrance, Peter, J	Herseim, Richard, M	Reisman, Darcy, S
Bhat, Anjana, N	Hsu, Wei-Li	Roberts, Dustyn, P
Binder-Macleod, Stuart	Hurd, Wendy, J	Rogers, Robert
Buchanan, Thomas S	Jaric, Slobodan	Royer, Todd, D
Butler, Robert, J	Jian, Pankaj	Rudolph, Katy
Cashen, Caitlin, M	Johnson, Brian, B	Rymer, W Zev
Chatterjee, Dhiman	Kaminski, Thomas W	Santare, Michael H.
Cohen, Shay	Kebaetse, Maikutlo, B	Sarkar, Kausik
Crenshaw, Stephanie J	Keefe, Michael	Schiavoni, Dominick, F
Davis, Irene	Kesar, Trisha	Schmitt, Laura, C
Dierks, Tracy, A	Knight, Christopher	Scholz, John
Ding, Jun	Krishnamoorthy, Vijaya	Snyder-Mackler, Lynn
Dong, Shufang	Lawrence, Jenn	Sun, Jian
Farach-Carson, M Cindy	Lei, Fulin	Szeri, Andras Z.
Farquhar, Sara	Li, Xiaoyi	Tate, Christine, M
Fallers, Melissa	Lloyd, David G.	Trager, Sarah, E
Fattah, Abbas	Lobo, Michele, A	Tseng, Ya-weng
Ferrand, Leanna	Maladen, Ryan	Tuday, Barbara, L
Fitzgibbons, John, T	Manal, Kurt	Turka, Christina, M
Fresconi, Frank, E	Manal, Tara Jo	Wilson, John D.
Galloway, Cole	Marchenko, Vitaliy	Wolos, Gregory, J
Gardinier, Joseph, D	Milner, Clare, E	Yoshida, Yuri
Getchell, Nancy	Mizner, Ryan, L	Zhang, Le
Glancey, James L.	Moore, James, F	Zhou, Hehe
Glime, Lauren, J	Muhlenforth, Daniel, R	Zifchock, Becky, A
Grabiner, Mark D.	Pabreja, Priya	