Restoring the complexity of locomotion in older people through arm-in-arm walking

Zainy M.H. Almurad[1,2], Clément Roume[1], Hubert Blain[1,3], Didier Delignières[1]
[1]Euromov, Univ. Montpellier, France, [2]Faculty of Physical Education, Univ. Mossul, Irak,
[3] Montpellier University Hospital
Email: zainyhajy70@gmail.com, didier.delignieres@umontpellier.fr

Presentation Preference: (1)

INTRODUCTION

The loss of complexity with advancing age has been documented in the field of locomotion, and is predictive of the propensity to fall [2]. It has been shown that two systems in close interaction tend to match their levels of complexity [3]. And we hypothesized that this matching of complexities could allow a restoration of complexity in the elderly. Then our aim was to study the effects of the prolonged interaction of two systems of different complexities: a healthy system and a system lacking in complexity.

METHODS

24 participants were involved in the experiment. They were divided into two groups, experimental (1) and control (2), each composed 12 participants. The experiment lasted four weeks, with three sessions per week, and three walking duo sequences of 15 minutes per sessions. At the beginning of each week participants performed a solo sequence of 15 min, at his/her preferred velocity.

Duo sequences consisted for the participants of Group (1) to walk in synchrony, arm-in-arm, with a young and healthy companion. In the Group (2), participants performed side-by-side walking with the healthy companion, but without any synchronization requirement.

A post-test (solo sequence) was performed two weeks after the end of the experiment.

RESULTS AND DISCUSSION

During duo sequences, the complexity of participants tended to match that of their companion.

At the beginning of the fourth week, the complexity of participants during the solo sequence reached the complexity level of the companion.

The restoration of complexity was preserved during the post-test, two weeks after the end of the experiment.

The results present evidence for the presence of a complexity matching effect in synchronized walking conditions. This result has important implications, especially for rehabilitation purposes. This experiment shows that the prolonged experience of complexity matching, with a healthy system, could allow restoring the complexity of deficient systems. Additionally, this effect seems persistent over time, at least within the time scale used in this experiment.

CONCLUSIONS

-Synchronized walking, between older participants and the experimenter, is dominated by a complexity matching effect.

-Complexity matching results in an attunement of complexities between the two participants, and an attraction of the complexity of the older participant towards that of the younger.

-A prolonged experience of complexity matching results in a perennial restoration of complexity in older people.

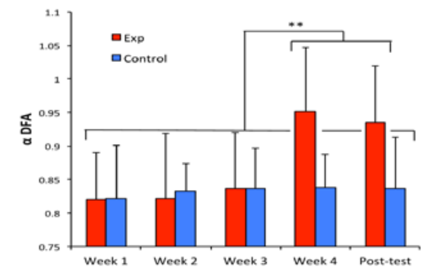

Fig 1. Average α-DFA exponents computed for participants in solo sequences

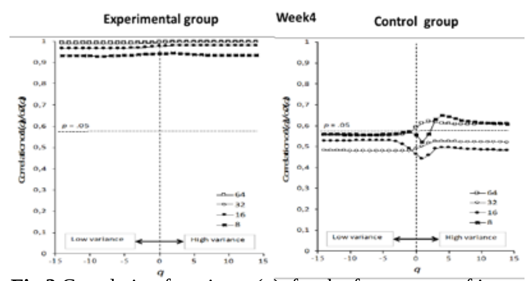

Fig 2.Correlation functions r(q), for the four ranges of intervals considered.

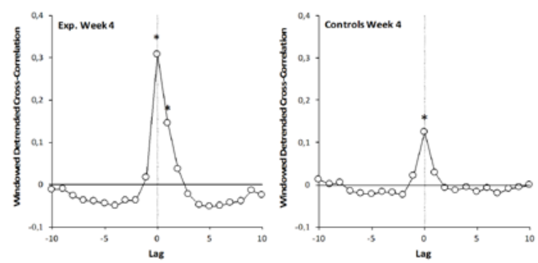

Fig 3.Averaged WDCC functions, from lag -10 to lag 10

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TRAINING WITH LATERAL STEPPING IMPROVES CLINICAL BALANCE TESTS IN OLDER ADULTS

Katherine Allen, Andreas Skiadopoulos & Nicholas Stergiou
Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: nstergiou@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: [**Podium**]

INTRODUCTION

One-third of older adults aged 65+ are susceptible to falling, mostly during walking [1]. We propose that older adults with age-related gait abnormalities can improve their walking ability and reduce their risk of falling by performing a lateral stepping training [2]. This proposal was based on our preliminary work that demonstrated that lateral stepping can significantly affect important mechanical characteristics of gait [2].

METHODS

Fourteen older adults aged 65+ underwent a lateral stepping training three times a week for six weeks. The lateral stepping training program adhered to current exercise prescription recommendations of the American College of Sports Medicine [3] and dosage was also supported by recent fall prevention research [4-6]. Each session consisted of 30 minutes of lateral stepping. The following instructions were given to participants on how to perform the lateral stepping training: i) keep head up while stepping laterally, ii) do not cross feet at any point, iii) feet and legs are to be pointed in the same direction as body, and iv) at no point can both feet be off the ground (i.e. no flight phase). They were also informed that they could increase their pace at the start of each session but may not decrease it at the next session. This promoted continued learning and prevented any plateau effect. Participants stepped laterally across a 10m section on an indoor track, changing direction at the ends thus alternating lead and lag legs (Fig. 1). Three minutes of lateral stepping was alternated with at least one minute of rest. At Baseline, after completion (Post) of the training, and six-weeks following completion (Retention), the participants were assessed regarding their i) comfortable treadmill walking speed, ii) the Timed-Up-and-Go (TUG) [7], iii) the modified Falls Efficacy (FES-I) [8], and iv) the Sensory Organization test (SOT) [9].

Figure 1. Training with lateral stepping.

RESULTS AND DISCUSSION

The six-week lateral stepping training significantly decreased the TUG and the FES-I scores, while increased the self-selected comfortable walking speed. These results were retained six-weeks after the completion of the intervention (Fig. 2). There was no effect on the SOT score but a tendency for an improvement. These results demonstrated the feasibility and, most importantly, the potential of our six-week lateral stepping training to improve clinical balance tests.

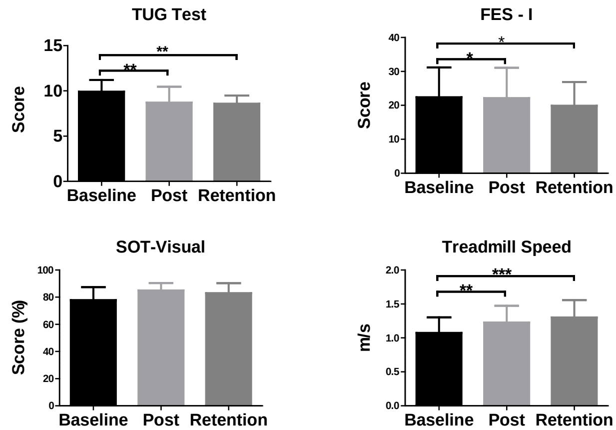

Figure 2: The intervention significantly improved performance in clinical measures of balance and the effects were retained for a six-week period following the completion of the intervention. ($p<.05$*; $p<.01$**; $p<.001$***).

CONCLUSIONS

The results indicate that a lateral stepping training has the potential to decrease fall risk during walking by improving the participant's balance and speed. The fact that these effects were also retained 6-weeks after the training is even more impressive. We are currently exploring the mechanisms that has resulted in these very serendipitous results.

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INTENSITY AND PATTERN OF DAILY PHYSICAL ACTIVITY OF CLAUDICATING PATIENTS

Cody Anderson[1], Hafizur Rahman[1,3], Hernan Hernandez[2], Sara A. Myers[1,3], Molly Schieber[1], Duy M. Ha[2], Sarah Baker[1], Panagiotis Koutakis[2,4], Kyung-Soo Kim[2], Constance Mietus[2], George P. Casale[2] & Iraklis I. Pipinos[2,3]
[1]Nebraska Biomechanics Core Facility, University of Nebraska at Omaha, Omaha, NE USA
[2]Department of Surgery, University of Nebraska Medical Center, Omaha, NE USA
[3]Department of Surgery and VA Research Service, VA Nebraska-Western Iowa Health Care System, Omaha, NE USA
[4]Department of Health, Human Performance and Recreation, Baylor University, Waco, TX USA
email: codypanderson@unomaha.edu

Presentation Preference: **Poster Only**

INTRODUCTION

Claudication is the most common manifestation of peripheral artery disease (PAD), producing significant ambulatory compromise [1]. Limited information exists on the free-living physical activity of claudicating patients [2]. Therefore, this study recorded the intensity level and daily pattern of physical activity in community-dwelling claudicating patients.

METHODS

Forty-four claudicating patients (age: 64.16 ± 6.55 years, BMI: 28.59 ± 4.73 kg/m^2) were recruited from the Vascular Surgery Clinic at the Veterans Affairs Nebraska-Western Iowa HealthCare System in Omaha, Nebraska. Physical activity of all patients was recorded using the ActiGraph (ActiGraph, LLC; Fort Walton Beach, FL) GT1M activity monitor worn on the hip. The Actigraph monitor is a lightweight instrument designed to measure human movement through changes in acceleration, measured as counts over one-minute time periods. Data from seven consecutive days were used for the calculations. We processed the data using the ActiLife software program.

RESULTS AND DISCUSSION

Table 1 summarizes the physical activity measures obtained for claudicating patients. The average daily activity of the claudicating patients showed a steady increase beginning approximately 05:30 until a peak plateau from 10:00-13:30 followed by a steady decrease until approximately 21:30, when the inactive time of day starts (Figure 1). The claudicating patient had a decreased daily physical activity output measured in steps and Metabolic Equivalents of Task (METs) when compared to previously published data on similar non-claudicating populations. Average physical activity intensity and peak intensity fluctuated very little during the day and rarely exceeded a light activity level (light =< 3 METs maximum effort, like casual walking or light housework).

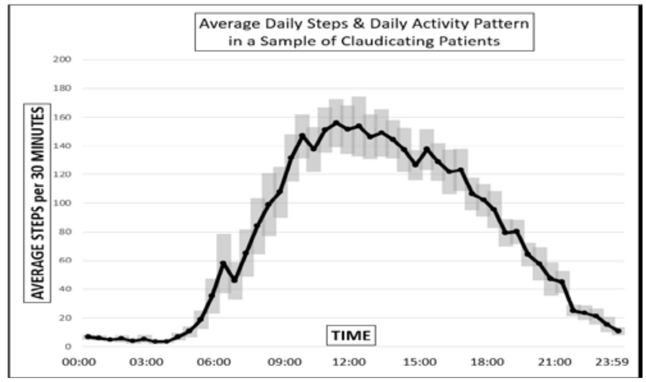

Figure 1: Average daily steps and daily activity pattern in claudicating patients. The black line is the average and the gray shaded bars represent standard error.

Approximately 1/3 of the standard active time period was spent in sedentary behaviors (<1.5 times' resting energy expenditure) and sedentary time was spread throughout the day mostly in short intervals between bouts of activity.

CONCLUSIONS

Our results objectively demonstrate the reduced physical activity of claudicating patients and describe their daily activity pattern. The intensity and the peak intensity of the physical activity of the average claudicating patient fluctuate very little during the day and rarely exceed above a light intensity level. Our measures establish much needed physical activity parameters to compare and correlate with biological data, morphological characteristics and therapeutic interventions.

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Table 1: Physical activity measures of claudicating patients (n=44)

Average Total Daily Steps	Mean ± SE = 3586.44 ± 298.0161 Median = 3260.36 95% Confidence Interval = 2985.44 - 4187.44
Average Daily METs per Minute	Mean ± SE = 1.4549 ± 0.0011 Median = 1.4537 95% Confidence Interval = 1.4527 - 1.4570
Average Daily Peak MET per Minute	Mean ± SE = 1.5783 ± 0.0068 Median = 1.5644 95% Confidence Interval = 1.5649 – 1.5917

*SE= Standard Error, MET=Metabolic Equivalents of Task

EFFECTS OF VARIATIONS IN TIMING AND MAGNITUDE OF FORWARD FORCES AT THE WAIST ON THE METABOLIC COST OF WALKING

Prokopios Antonellis, Arash Mohammadzadeh Gonabadi & Philippe Malcolm
Department of Biomechanics and Center for Research in Human Movement Variability,
University of Nebraska at Omaha, Omaha, NE USA
email: pantonellis@unomaha.edu, web: http://coe.unomaha.edu/brb

Presentation Preference: [**Poster** or **Podium**]

INTRODUCTION

During walking, the need to generate forces creates a metabolic demand. Gottschall and Kram found that a constant forward traction force applied at the waist reduced metabolic cost by 47% when pulling with 10% of a subject's body weight [1]. They also found that higher forward forces produced less reduction in metabolic cost because this led to an increase in braking impulse [1]. However, there is little information about the effects of non-constant traction forces.

The purpose of the present study was to investigate the effects of timing and magnitude of different forward force profiles on metabolic cost. We hypothesized that forward force profiles that roughly coincide with the propulsion phase would reduce metabolic cost whereas force profiles that coincide with the braking phase would increase metabolic cost.

METHODS

We developed an attachment structure that allows applying forward force profiles from a cable-pulling robot (HuMoTech, Fig. 1) tied to a waist belt with a load cell (Futek) [2, 3]. One healthy participant walked on a treadmill at 1.25 $m \cdot s^{-1}$. We also inclined the treadmill by 5% which allowed applying a net zero apparent force on the participant while still keeping the cable taut.

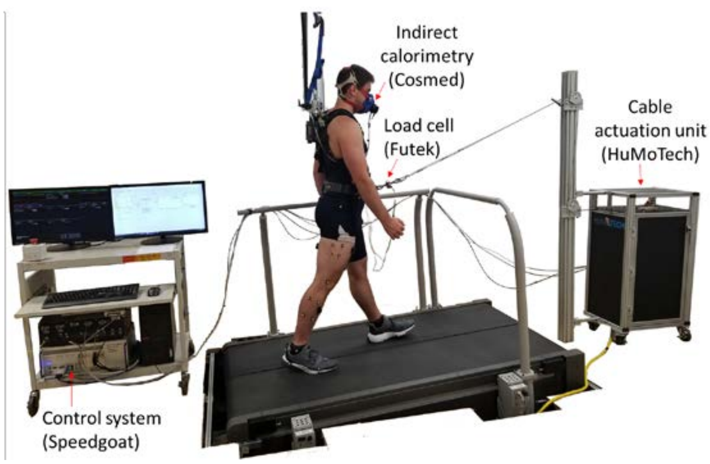

Figure 1. Experimental setup.

We developed a controller that applied 33 force profiles as a function of step time [2]. Each condition lasted two minutes.

We measured rates of oxygen consumption and carbon dioxide production (Cosmed, K5). We estimated steady-state metabolic cost for each condition using a method for estimating instantaneous metabolic cost [4]. The reduction in metabolic cost was calculated by subtracting the metabolic cost of walking with a constant net zero forward force.

RESULTS AND DISCUSSION

We found that conditions with higher horizontal forces and longer assistance durations have higher reductions in metabolic cost (Fig. 2). We found the highest reduction in metabolic cost (22%) in the condition with a peak force of 12% of body weight (BW) at 70% of the step cycle. We also found the highest increase in metabolic cost (6%) in the condition with a peak force of 5% of BW at 40% of the step cycle. This timing coincides with the timing of maximum horizontal center of mass deceleration [5] which confirms our hypothesis that forward forces that coincide with the braking phase increase metabolic cost. Determining the optimal assistance profiles from this study could guide the development of powered walkers and assistive rehabilitation devices [6].

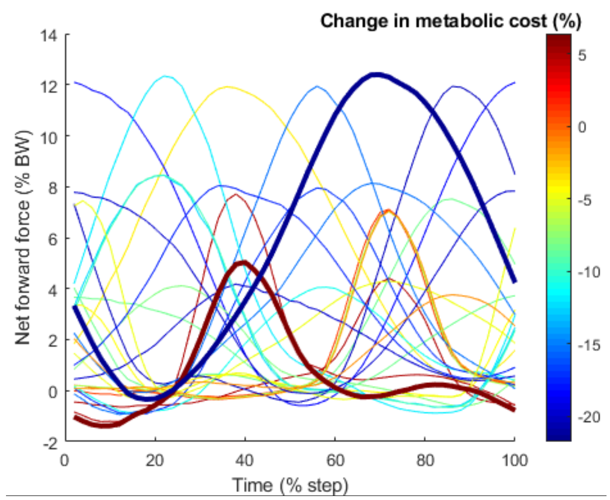

Figure 2. Net forward force profiles plotted versus step time. Colors indicate reductions and increases in metabolic cost. Conditions with highest reduction and highest increase are indicated with thick line (blue and brown).

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MUSCLE OXYGENATION IN PATIENTS WITH PERIPHERAL ARTERY DISEASE DURING WALKING WITH AND WITHOUT AN ANKLE FOOT ORTHOSIS

Anthony Arellano[1], Hafizur Rahman[1,2], Iraklis Pipinos[2,3], Jason Johanning[2,3], Sara Myers[1,2]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]Department of Surgery and VA Research Service, VA Nebraska-Western Iowa Health Care System, Omaha, NE USA
[3]Department of Surgery, University of Nebraska Medical Center, Omaha, NE USA
email: aarellano@unomaha.edu

Presentation Preference: **Poster Only**

INTRODUCTION

Peripheral artery disease (PAD) is a cardiovascular disease caused by blockages of the leg arteries that reduce blood flow. Claudication, a cramping pain or tiredness in the ischemic legs, is the most prevalent symptom of PAD and it impairs walking ability [1]. The time of claudication pain onset and the time at which claudication pain forces the patients to stop walking are known as initial claudication time (ICT) and absolute claudication time (ACT) respectively. Previous studies have shown that muscle oxygenation starts significantly lower and declines faster in the calf muscles of patients with PAD compared to healthy controls [2, 3]. An ankle foot orthosis (AFO) can improve functional status and quality of life in patients with PAD by absorbing and returning mechanical force during walking. We hypothesized oxygenation levels would be higher in patients with PAD walking with the AFO, enabling patients to walk further.

METHODS

Seven male subjects with PAD (age: 70.75 ± 6.58 years, BMI: 32.64 ± 7.45 kg/m^2) were recruited through the clinics at the Nebraska-Western Iowa Veterans Affairs Medical Center. All subjects were diagnosed with arterial occlusive disease resulting in claudication symptoms. The PortaMon (Artinis Medical System) is a muscle oxygen monitor that uses near infrared spectroscopy to measure the muscle oxygen saturation of the local muscle. This monitor was attached to the gastrocnemius while subjects performed a standardized graded treadmill test. The protocol included walking at a speed of 0.89 m/s (2.0 mph) that began at 0% grade and increased 2% grade every two minutes. The onset of claudication pain was recorded as ICT. The subjects continued to walk until claudication pain forced them to stop, which was recorded as ACT. The subjects were then placed into seated rest until pain subsided. The subjects repeated the same test protocol twice, once without and once while wearing the AFO; the conditions were counterbalanced across subjects. Tissue (muscle) oxygen saturation, StO_2, was recorded at ICT and ACT for both AFO and without AFO (NAF) trials. A paired-sample t-test was used to determine the differences between the NAF and AFO ($p < 0.05$).

RESULTS AND DISCUSSION

The StO_2 value at ICT was 36.97% higher, a significant increase while using the AFO compared to NAF ($p = 0.016$; Figure 1). Similarly, at ACT the StO_2 significantly increased 30.19% for AFO trial ($p = 0.029$; Figure 1). This suggests using the AFO will improve the oxygenated hemoglobin delivery to working muscle during exercise. Therefore, delaying pain onset and enabling patients with PAD to sustain walking for longer periods of time.

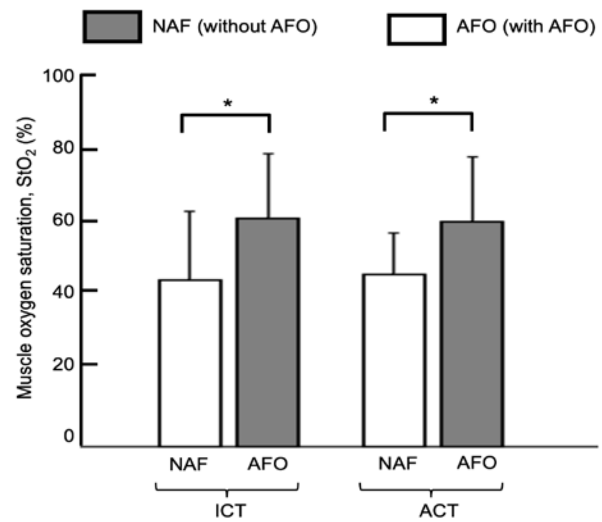

Figure 1: The StO_2 percentage at ICT and ACT for both NAF and AFO trials. * indicates statistically significant difference between NAF and AFO ($p < 0.05$).

CONCLUSIONS

Our results demonstrate that using the AFO significantly improved the muscle oxygenation in calf muscle in patients with PAD. The current study includes only seven patients, so larger trials are needed to increase the statistical power of the study. Future studies should examine how StO_2 impacts muscle activity, lower extremity torque and power, and energy cost.

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THE ASTRO XO™ EXOSKELETON ALTERS ANKLE KINETICS IN HEALTHY INDIVIDUALS

[1] Blake Beier, [1]Angel Gonzalez, [1]Erica Hedrick, [1]Jeff Patterson, [1]Corbin Rasmussen, [1,2,3]Iraklis Pipinos, [1]Sara Myers
[1]The University of Nebraska Omaha, Omaha, NE, USA
[2]University of Nebraska Medical Center, Omaha, NE, USA
[3]Omaha VA Medical Center, Omaha, NE, USA
Email: bbeier@unomaha.edu, web: cobre.unomaha.edu

Presentation Preference: (1) **Poster or Podium**

INTRODUCTION

The ankle joint is one of the most important for walking, producing 60% of the summed ankle, knee, and hip positive mechanical work for each stride [1,2]. Ankle weakness results in reduced torque and power production, leading to slower self-selected speed [3]. Slower preferred walking speed correlates with poorer physical function, health status, more disabilities, and increased medical-surgical visits [4]. Many orthotic and exoskeletal devices have been created to restore proper ankle function by promoting ankle plantar flexion.

The ASTRO XO^{TM} Exoskeleton (AXO) is a passive, flexible device that promotes forward propulsion during stance, assisting plantar flexion and improving ankle range of motion (ROM) [5]. Increasing plantar flexor torque and ankle ROM has been suggested to improve gait deviations, such as walking speed [6]. While the AXO was originally designed to assist gait for people suffering from plantar fasciitis, it is our interest to see the AXO's effect on the ankle, especially during push-off, for pathological populations that have reduced ability to propel with the ankle.

First, we needed to establish how the AXO impacts gait in healthy individuals. Thus, this study assessed the effects of the AXO on ankle kinetics and kinematics for healthy, young individuals. We hypothesized that wearing the AXO will not affect the dominant leg ankle angle throughout stance phase, but will increase the peak ankle moment and peak ankle power due to the passive elastic components storing and returning energy.

METHODS

Four young, healthy individuals (3 males, 1 female, 23.25 ± 1.25 yrs, 75.5 ± 12.4 kg) walked for one minute with and without the AXO on their dominant leg. Using 3D motion capture and an instrumented treadmill, set to 1.25 m/s, ankle angle, moment, and power were measured during treadmill walking. Data was processed using Vicon Nexus tracking software and analyzed using C-Motion's Visual 3D. All variables were collected in the sagittal plane and were time normalized to stance phase of the gait cycle, and all kinetic variables (ankle moment and power) were normalized to subjects' body mass in kilograms. The average of each subject was taken and used as a representative sample of the effects from the AXO device.

RESULTS AND DISCUSSION

As hypothesized, ankle range of motion showed very little differences when wearing or not wearing the AXO. The peak plantar flexion angle while wearing the AXO produced a 1.50% decrease compared to without. Peak dorsiflexion demonstrated a 0.51% increase while wearing the AXO. Kinetic variables showed relatively small changes. Ankle power data showed that energy was generated earlier in stance when wearing the AXO, compared to without the AXO (Figure 1).

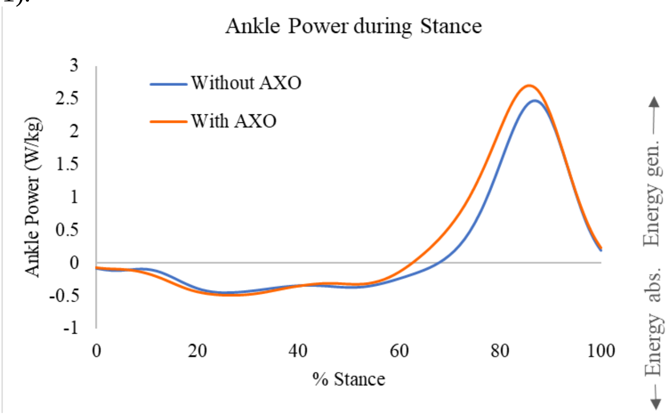

Figure 1: Ankle power without the AXO (blue) and with the AXO (orange) during stance phase of gait.

Ankle power data showed that the AXO device produces an 8% increase in positive power compared to without the device. Additionally, ankle moment data showed that the AXO produces a 3.21% decrease in negative moment, and a plantar flexor torque earlier in the gait cycle.

CONCLUSIONS

The study demonstrated that our initial hypothesis that the AXO device does not produce significant changes in ankle joint angle was correct. Alternatively, our hypothesis that the kinetic variables of the ankle moment and power would increase while wearing the AXO was partially supported. Ankle peak moment decreased in magnitude while ankle power peak had a small increase that made peak energy generation occur earlier in stance.

Since the AXO device is designed to help individuals with decreased ankle power, a future study could repeat this experiment with people who need plantar flexor assistance. In that study, it is likely to see a more pronounced difference in ankle moments and powers when comparing walking with and without the AXO device.

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Visual Contributions to balance control during gait

Kyle Brozek[1], BS, Zachary Motz[1], MS, Takashi Sado[1], BS, Mukul Mukherjee[1], PhD.
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: kbrozek@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: [**Poster Only]**

INTRODUCTION

Balance control during gait is affected by the orthogonality of movement[1,2]. Additionally, it has been shown that the direction of optic flow (OF) influences balance control during gait[3,4]. However, since these studies have only considered sudden visual perturbations, we still don't know if the visual feedback effects are specific to the direction of continuous OF. We propose to isolate the contributions of continuous OF to the orthogonal relationship between balance and gait control during treadmill walking using a series of conditions. Manipulating the direction of OF using a CAREN (Motek Medical, Amsterdam, Netherlands) virtual reality treadmill environment will isolate these visual contributions in human subjects as they walk. We plan to tease out the effect of OF direction on the relationship between gait and balance control by having healthy young adults perform a series of treadmill walking trials while immersed in a VR environment. This will be done by manipulating the direction of walking and the direction of OF through controlled oscillations of the treadmill and the VR environment. As these oscillations diverge from congruent to incongruent conditions, we anticipate that a synchronized change in the gait-balance relationship.

METHODS

20 healthy adults (19 to 35 years), who do not have any lower limb dysfunction, cognitive impairments, cardiovascular or other abnormalities that could affect walking will be recruited. The protocol will involve walking on the CAREN in the Gait laboratory in the Department of Biomechanics.

The CAREN consists of a split-belt, instrumented treadmill suspended on a six-degree-of-freedom motion-based platform. It is outfitted with 12 motion capture cameras which allow the collection of kinematic locomotion data at 100Hz. 17 markers at specific anatomical landmarks (foot, pelvis, and trunk), will be placed on participants to allow collection of data.

The experimental protocol (Table 1) will consist of five 5-minute walking trials at a self-selected preferred walking speed (PWS). The first trial will be to familiarize with the setup. All trials will be performed in an immersive VR environment where a virtual path will be displayed on a screen in front of the treadmill. After the first five-minute baseline trial in which the VR and the support surface will not be oscillating, the following 4 trials will comprise of a random order of trials with either VR environment or treadmill oscillations or both (congruent or incongruent). When both treadmill and VR are oscillating (trials 3 and 4), participants will walk at a PWS while the platform and the virtual path both oscillate in the same (trial 3) and opposing (trial 4) directions.

RESULTS AND DISCUSSION

We expect that the results of this study will allow us to determine the contribution of visual feedback on the orthogonal relationship between gait and balance control during treadmill walking. We hypothesize (Figure 1) that the orthogonal relationship between gait and balance control will reverse during normal treadmill walking if visual feedback is reversed (congruent to incongruent). Additionally, the orthogonal relationship between gait and balance control will demonstrate a strong linear relationship with OF direction during normal treadmill walking.

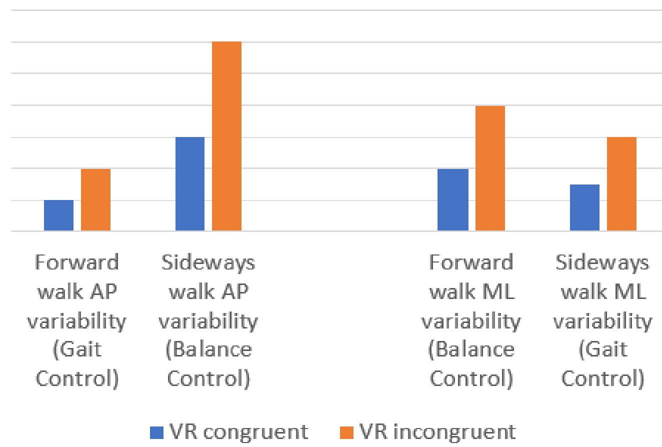

Figure 1: Congruent vs. Incongruent optic flow during AP and ML walking

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Table 1: Experimental protocol for walking trials

	Baseline	Incongruent VR	Incongruent Gait	Congruent VR-Gait	Incongruent VR-Gait
Treadmill State	Non-oscillatory	Non-oscillatory	Oscillating*	Oscillating*	Oscillating*
VR State	Non-oscillatory	Oscillating*	Non-oscillatory	Oscillating*	Oscillating*

* *between +19 and -19 degrees*

Evaluation of Leg Press instrumentation

Russell Buffum[1], Adam B. Rosen[2], Brian A. Knarr[1]
[1]Department of Biomechanics, University of Nebraska Omaha, Omaha, NE USA
[2]School of Health and Kinesiology, University of Nebraska Omaha, Omaha, NE USA

email: rbuffum@unomaha.edu
Presentation Preference **Poster Only**

INTRODUCTION
For patients with an injury to their lower limb a common therapy includes using a standard leg press to strengthen muscles of the limb. As the leg press is a bilateral machine, and the machinery is not equipped to measure the force applied during each therapy session, it is unknown to clinicians how force is generated for each individual limb. This is of particular importance in unilateral injuries as the uninjured limb may be performing much of the force generation limiting the potential benefits of the exercise. To address this limitation we have developed a low-cost modular instrument designed to interface with a standard leg press to individually measure the force provided by each leg. Overall the goal of this project was to aid in the detection of asymmetric patterns of leg strength in patients such as ACL, TKA, and patellofemoral pain populations. As a first step, this study established the validity of the custom instrumentation and determined the baseline force patterns generated by young, healthy individuals across a range of target weights.

METHODS
Design: Load cells were positioned to collect heel to toe, and left to right with forces collected in parallel orientation. Data was collected through H30A bar load cells and independently amplified HX711 amplifiers. An ATmega328P at 60hz was used to process and transfer data for logging. (Figure 1)

Figure 1: Participant using instrumentation platforms strapped to a standard leg press.

15 healthy participants between ages 19-35 were recruited and consented for this study. Participants had no current or prior history of chronic hip, knee, or joint pain, illness, no pathology affecting the musculoskeletal system, and no history of muscle disorders. A one-repetition max was determined for leg press to normalize data based on self-reported fitness level, age and gender.[1]

Six repetitions were recorded, starting at no weight increasing in 10% increments to 50% of their determined one-repetition max. Data were collected for all six rep weights, however the 0% weight was disregarded due to high inconsistency with no resistance for participants to control. Data were normalized across all trials starting and ending at 50% of the targeted weight for each repetition. All subject data were normalized to 200 data points across all repetitions and averaged to gather a base line index between right and left (Figure 2).

RESULTS AND DISCUSSION
A base line maximum for one leg (62.08% ± 3.15%) and a minimum of (38.01% ± 5.48%) represents the range for healthy participants. Participant strategies for moving the weight always showed a pattern transferring weight between both legs to allow a distributed load time between limbs.

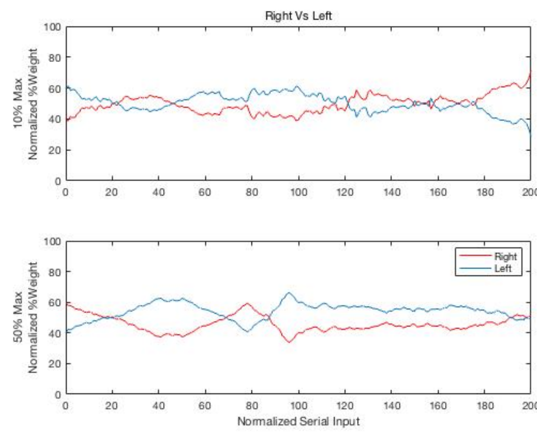

Figure 2: Rep-1 at 10% of 1-Rep-Max (top), Rep-5 at 50% of 1-Rep-Max (bottom). Right vs. left averaged across subjects.

CONCLUSIONS
The results suggest a generalized strategy and comparable baseline force values generated by young and healthy participants. The implication of this work brings a new tool designed for clinicians to access injured populations and their rehabilitation progress. Future research should consider weight compensation strategies from left to right vs. heel to toe and leg dominance, as well as changes to patterns due to injury or pathology.

ACKNOWLEDGEMENTS NIH P20GM191090 and R15 HD094194, University of Nebraska FUSE grant

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The effect of sensory input on the temporal structure of center of pressure in stroke survivors

Samantha Chong, BS, Takashi Sado, BS, Mukul Mukhurjee PhD.
Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: schong@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: [**Poster Only**]

INTRODUCTION

Stroke is the leading cause of disability that affects 17 million people worldwide. Patients post stroke suffer from maintaining balance because the brain may not be able to receive or process visual, vestibular and proprioceptive sensory information: all of which contribute towards maintaining stability. Information provided by vision is important for spatial orientation, as it develops an environmental perspective. Proprioception is detected through the stretching of tendons and surrounding tissue, and is able to help the brain determine spatial location. The vestibular system provides the sense of balance detecting rotations and linear accelerations through the vestibulo-ocular reflex. The vestibular system is important in maintaining spatial orientation and helps override sensory conflict. Postural control is a problem in stroke because it affects people carrying out activities of daily living (ADL).

It was hypothesized that when sensory feedback is absent or unreliable, balance control in stroke survivors will be worse than healthy age-matched controls. In this study, chronic stroke survivors and healthy age matched adults were recruited to go through the Sensory Organization Test with the objective of determining the effect of the contributions of each of the different sensory systems for maintaining balance during perturbed and unperturbed standing tasks.

METHODS

Data from 9 chronic stroke survivors and 9 healthy age-matched adults who underwent a sequence of standardized balance testing (the sensory organization test) was analyzed for this study. This series of tests allows us to look at the contribution of each sense towards maintaining balance on The SMART balance Master (NeuroCom International Clackamas, OR, USA). Specifically, based on the center of pressure (CoP) data in AP and ML direction, DFA was calculated to analyze long-range correlations in postural sway data. Other variables, such as root mean square (rMS) and sway range in both directions, as well as sway path was calculated. A 2 x 3 multi-factorial ANOVA was used to measure (groups: post stroke vs healthy x condition C1, C2, and C3) in SOT. And 2 x 4 multi-factorial ANOVA was used to measure (groups: post stroke vs healthy x condition C1, C4, C5, and C6) in SOT. Alpha level was set to 0.05 and further significance was tested using Turkey's HSD post-hoc test.

RESULTS AND DISCUSSION

There was no significant condition effect or interaction between the conditions and groups between the stroke group and healthy age matched group when the visual contribution (Conditions 1 to 3) was tested on the static surface for postural control.

There were significant differences in the rMS_AP (Figure 1), and range_AP (Figure 2), when the multisensory contributions were tested during the dynamic support surface conditions. However, there were no significant interactions present between the conditions and groups.

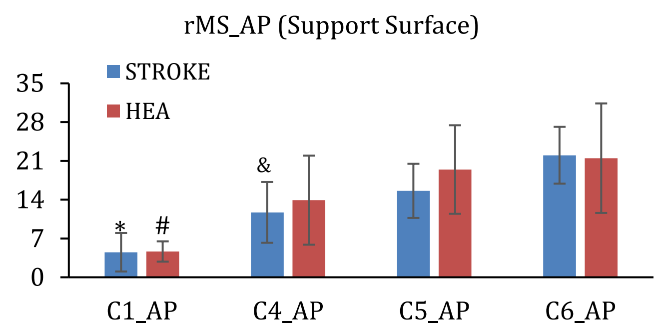

Figure 1 shows the average value of rMS in AP direction (mm) between stroke and healthy age matched group. * Indicates significant differences between C1 to C5 and C6 for stroke. # Indicates significant difference between C1 to C4, C5 and C6 for healthy. & Indicates that C4 is significantly different compared to C6

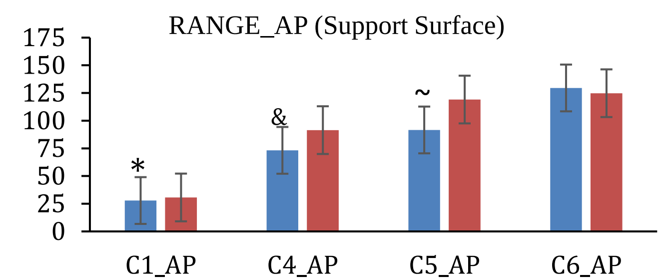

Figure 2 shows the average value of range in AP direction (mm) between stroke and healthy age matched group. * Indicates significant differences between C1 to C4, C5, and C6 for stroke. & Indicates that C4 is significantly different compared to C6. ~ Indicates that C5 is significantly different compared to C6.

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Acknowledgement

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BIMANUAL COORDINATION USING PROSTHETIC SIMULATORS

Christopher Copeland[1], James Pierce[1], Keaton Young[1], & Jorge Zuniga[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: ccopeland@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: [(3) **Poster Only**]

INTRODUCTION

The Centers for Disease Control and Prevention estimates that roughly 1,500 babies are born every year with upper limb reductions [1]. There were a total of 1.6 million people living with loss of a limb in 2005. This number is projected to double to 3.5 million by the year 2050 [2]. While prosthetics aim to enhance the function of these individuals, it is estimated 56% of prosthetic users reject their prosthesis [3].

There is little literature which investigates and describes the motor control mechanisms that may explain this high prosthesis rejection rate in children. This lack of information is due, in part, to the low availability of children with upper limb reductions to participate in research studies. Due to this restriction, many studies are limited in power because of their small size of potential subject pools. One relatively recent proposed solution to this problem is the employment of “prosthetic simulators”. These devices serve as functional homologues to the prostheses prescribed to children with upper limb deficiencies but can generally be fitted to any typically developing child or adult.

The purpose of this investigation was to determine the efficacy of prosthetic simulators by examining movement asynchronies during a bimanual coordination task in prosthetic use in upper limb deficient (ULD) children compared to typically developing (TD) children. We hypothesized that bimanual coordination would be significantly less in both ULD and Simulator groups compared to the control group.

METHODS

The investigation was approved by the UNMC Institutional Review Board. For children under six years of age, the study was explained to both the parents and children, before parents signed a parental permission. For children aged six years or older, an assent was detailed by the principle investigator, which was signed by both parties.

Children with upper limb deficiencies (n = 5) with body powered prosthetic devices and healthy typically developing age and sex matched children (n = 5) performed bimanual reaching motor tasks. The typically developing group performed these tasks both with (TD-Simulator) on their non-preferred hand and without (TD-Control) using the prosthetic simulator.

Bimanual reaching tasks were used to assess overall coordination and limb synchrony [4]. Each subject started from a standardized position and was asked to reach forward to grasp an instrumented tray, move it to a ledge, and finally return their hands to the standardized resting position. Movement times were noted for each component of the task.

RESULTS AND DISCUSSION

Mean movement times of task components for all groups (ULD, TD-Control, and TD-Simulator) are illustrated below (Figure 1). Two-way analysis of variance yielded a significant main effect of limb condition (ULD, Simulator, and Control). Values that are positive indicate the right limb leading, while negative values indicate that the left hand is leading during the task. Thus, values closer to zero indicate increased synchrony between limbs. Bimanual coordination between groups for each task was not significantly different. However, trends from Figure 1 highlight that bimanual asynchrony is present in the ULD group, as they often lead with their preferred hand.

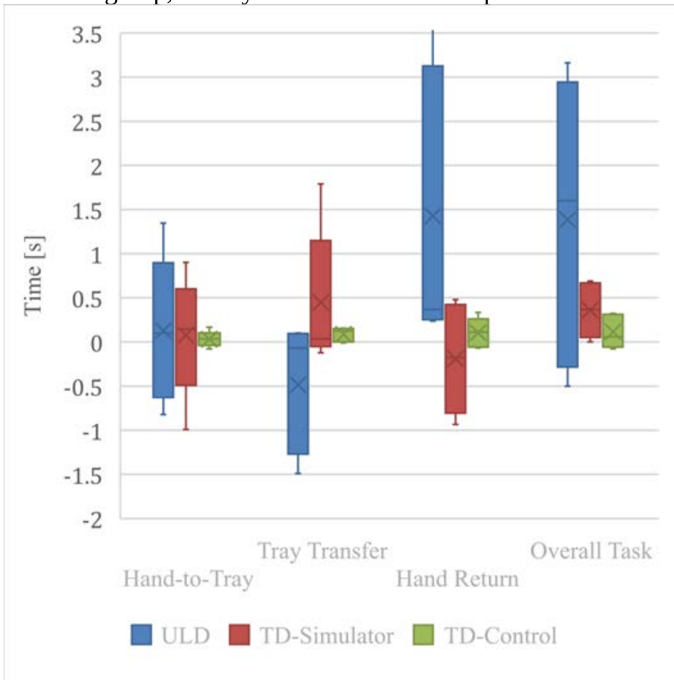

Figure 1: Movement time and asynchrony during bimanual coordination task.

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ASSESSMENT OF 3D PRINTED FINGER PROSTHESES: A COMPARATIVE CASE STUDY

Claudia Cortes Reyes, Roberto Saavedra, Keaton Young & Jorge Zuniga
Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
Email: ccortesreyes@unomaha.edu

Presentation Preference: (3) **Poster Only**

INTRODUCTION

The number of upper limb amputations is expected to rise to 3.6 million by the year 2050 [1]. Finger loss is the most common upper limb amputation and significantly impacts daily function, coordination and quality of life [2]. Despite the increase in functionality provided by a prosthetic, a recent study found that 56% of upper limb amputees abandon their prosthetic device due to functional, aesthetic or other constraints in the current market [3]. Traditional prosthetic fabrication is a lengthy process that spans multiple days, therefore there exists a high need for an accelerated method of production. Advancements in computer aided design (CAD) programs allow for the utilization of photogrammetric methods to create customized sockets relative to patient specific anthropometrics. The purpose of this study is to describe the development of transitional 3D printed prosthetics for partial finger amputees and to describe the qualitative and functional characteristics when compared to a commercially available partial finger prosthesis.

METHODS

The research subject evaluated in this study was a 72-year-old male (height 177.8 cm; weight 81.6kg) with an acquired traumatic amputation of the index finger at the proximal interphalangeal joint (PIP) on the left hand (non-preferred) distal to the metacarpal joint (MCP). The subject had acquired the MCP-Driver™ finger prosthesis from NAKED Prosthetics Inc. prior to participating in study.

The MCP-Driver*™* is a partial finger prosthetic that uses a linkage driven mechanism for the articulation of a partial finger amputation. This device is fabricated using titanium, stainless steel, silicone and medical grade nylon. The 3D printed finger prosthesis was designed and scaled to be as proportional and symmetric to the length and circumference of the participant's non-affected finger. The scaling of the 3D printed prosthesis was performed remotely through the use of photogrammetric methods of anthropometric measurement.

The research subject performed the Box and Block Test (BBT), which provided a functional outcome measure of unilateral gross manual dexterity. Two weeks after testing was completed in the laboratory, the subject performed a satisfaction survey, Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 2.0) [4].

RESULTS AND DISCUSSION

During the Box and Block Test (BBT), the subject moved the same number of blocks during the one-minute trial with the 3D printed finger prosthesis and the MCP-Driver *™*. Table 1 displays all results of the BBT when using and not using the prosthesis, as well as the non-affected hand. Furthermore, the subject demonstrated a 60% improvement in task-specific efficiency when compared to the non-affected hand.

Table 1. Box and Block Test

Condition	Blocks per Minute
3D Printed Prosthesis	22
NAKED Prosthetics - MCP-Driver	22
No Prosthesis	18
Non-Affected Hand	30

Results of the QUEST 2.0 device satisfactory survey, observed that the 3D printed finger prosthesis scored slightly higher (3.3 ± 1.2), as compared to the MCP-Driver (2.5 ± 0.5). Table 2 describes the results for the QUEST 2.0 survey for both the 3D printed finger prosthesis and the MCP-Driver *™*.

Table 2. Quebec User Evaluation of Satisfaction with assistive Technology (QUEST) Ratings.

How Satisfied Are You With:	3D Prosthetic	NAKED Prosthetics
Dimensions (size, height, length, width)	4	3
Weight	4	3
Adjustments (fixing, fastening)	2	2
Safety (secure)	2	2
Durability (endurance, resistance to wear)	4	2
Ease of Use	5	2
Comfort	3	3
Effectiveness (degree to which device meets your needs)	2	3
Device Satisfaction	**3.3 ± 1.2**	**2.5 ± 0.5**

1 = not satisfied at all, 2 = not very satisfied, 3 = more or less satisfied, 4 = quite satisfied, 5 = very satisfied. Total Device, Service and Satisfaction means calculated using average of each item.

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Contributions of Individual Differences and Context on Dual-Task Performance in Adults: Maintaining Independence and Well-Being in Older Adulthood

Kyle Doerr[1], Hyeon Jung Kim[2], Farahnaz Fallah Tafti[1], Dawn Venema[3], Julie Blaskewicz Boron[2], Jennifer Yentes[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]Department of Gerontology, University of Nebraska Omaha, Omaha, NE USA
[3]Physical Therapy Education, University of Nebraska Medical Center, Omaha, NE USA
email: kldoerr@unomaha.edu

Presentation Preference: Poster only

INTRODUCTION

The relationship between cognitive function and movement has been well established [1], as has decreased cognitive and motor performance of older adults when tested in dual-task (DT) paradigms. DT ability, often defined as the ability to engage in two motor and/or cognitive tasks at the same time, is essential for performing daily tasks such as cooking and navigating environments when walking. A decrease in cognitive abilities associated with older age have been linked to falls and fall risk [2, 3]. Walking while talking is a common everyday DT activity, however, when people are in their homes, or other common environments, they may not use appropriate caution, putting them at higher risk of neglecting the primary task, walking. Currently, the literature is sparse on ecologically valid DT paradigms. Therefore, the purpose of this study is to begin to address these gaps by investigating the dual-task cost of gait in older adults while having a telephone conversation compared to dual-task cost in younger adults under the same given conditions. Gait of older adults has been found to be more affected by DT paradigms than their younger counterparts [4, 5], potentially due to a deficit in attention allocation, gait requiring additional attention, and/or a decline in cognitive resources. Talking on the phone is an ecologically valid task that is performed on a regular basis. It has been hypothesized that older adults will demonstrate a greater dual-task cost of gait while talking on the telephone compared to healthy, young adults.

METHODS

This project is going to include a total of 20 subjects recruited from the community; 10 healthy young control subjects (19-30 years old) and 10 subjects healthy older individuals (70 years and older). Participants will be screened for conditions that may confound the results such as neuromuscular disorders and difficulty hearing. Participants are deemed eligible based off a health history form and an audiometry test. Participants attend two visits within 15 business days of each other. During visit 1, subjects will be consented, screened for participation, participate in a hearing test, complete physical activity and cognitive questionnaires, and engage in telephone conversation via cell phone while seated. During visit two, subjects will go through two randomized walking conditions. The two walking conditions are walking only or walking and participating in a conversation on a cell phone. In regard to conversations, subjects will be asked to rank their preference in the conversation topics from least favorite to favorite topic. Two conversations will be conducted per visit, each lasting three minutes long with a break of at least five minutes in between the two conversation increments. Conversations will be recorded for transcription and analysis at a later date. For the walking conditions, subjects are asked to walk three minutes under two randomly presented conditions: 1) walking only or 2) walking while having a phone conversation. When performing walking conditions, subjects are asked to walk around the perimeter (roughly 100 feet total) of the laboratory continuously for three minutes at a self-selected pace. A pressure-sensing walkway is positioned along one side of the room to record their steps and provide information regarding gait speed, step length, timing, and width. Gait data will be averaged within each walking bout. The following equation will be used to calculate dual-task cost (DTC):

$$DTC = ((DT - ST)/ST) * 100.$$

where DT is dual task condition and ST is the single task condition. A positive DTC value would indicate a benefit and a negative DTC value would indicate a cost. The group mean differences in dual-task cost will be calculated using an independent t-test.

RESULTS AND DISCUSSION

Data collections for this project are still on-going and will be completed in time to present at this conference. Therefore, results and discussion are unavailable at this time.

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COLLISION WORK PERFORMED BY PATIENTS WITH PERIPHERAL ARTERY DISEASE

Alex Dzewaltowski[1], Iraklis Pipinos[2,3], Jason Johanning[2,3] & Sara Myers[1,2]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE, USA
[2]Omaha VA Medical Center , Omaha, NE, USA
[3]University of Nebraska Medical Center, Omaha, NE, USA
email: adzewaltowski@unomaha.edu, web: cobre.unomaha.edu
Presentation Preference: [Please indicate (1) **Poster or Podium**]

INTRODUCTION

Collision work has the potential to be an important consideration when designing powered exoskeletons. Collision work is energy dissipated into the surrounding environment from impact, in this case, upon heel strike. When designing an exoskeleton for patients with peripheral artery disease (PAD), harvesting energy lost to collision work could be a valuable mechanism to improve walking performance. Devices designed to utilize the normally dissipated energy to assist propulsion for improved walking performance are under-explored [1, 2]. This study assessed average collision work in patients with PAD compared to healthy, age-matched controls. The purpose of this study was to assess the validity of healthy, older individuals as a model for patients with PAD for fundamental research comparisons when designing assistive exoskeleton devices.

METHODS

Fifteen subjects with PAD were recruited by the Veteran's Affairs Nebraska-Iowa Health Care System and five healthy, age-matched controls (Age: 67.4 ± 9.5 years) performed over-ground walking trials at their self-selected speed. Subjects walked over eight in-ground AMTI force plates until six quality foot-to-force plate contacts were achieved for each leg. Three-dimensional kinematics were collected using 17 motion capture cameras (Cortex 5.1, Motion Analysis Corp, Santa Rosa, CA) with retro-reflective markers placed at specific anatomical locations according to a modified Helen Hayes marker set [3].

Collision work was calculated by multiplying each subject's peak ground reaction force for each axis (X,Y,Z) by their corresponding velocity at heel strike [4]. Their corresponding velocity at heel strike was calculated from the average change in position of the retro-reflective marker placed on the heel over a 0.04 second period before initial heel-to-ground contact. The short time frame is to avoid the average velocity being affected by the foot still being in swing phase of gait. The magnitude of this three-dimensional vector was then computed and normalized by body mass to units of watts per kilogram. The velocity of the retro-reflective marker placed on the sacrum was also determined similarly for approximation of the subject's preferred walking speed. Differences between mean collision work performed by patients with PAD and controls was assessed using a 2-sample t-test.

RESULTS AND DISCUSSION

Collision work performed by patients with PAD was not significantly different from control subjects ($t = 0.73$, $p = 0.47$). Therefore, healthy, older subjects are a viable population to conduct exoskeleton design research for exploration into collision work as a mechanism for improving walking performance. Average collision work and ankle power at push-off for patients with PAD was 2.54±0.83 and 1.99±0.50 watts/kg respectively. This suggests that collision work, if correctly transferred, could be a sufficient energy source for assisting push-off. In Figure 1, sacrum velocity is correlated to the magnitude of collision work performed. This is to be expected since work is directly related to velocity. These results emphasize the importance of controlling walking speed when exploring collision work to eliminate its confounding impact.

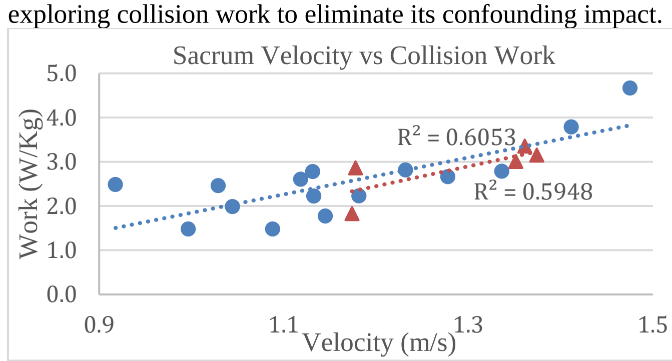

Figure 1: Blue circles are patients with peripheral artery disease (PAD) and red triangles are healthy, age-matched controls. This chart showcases the relationship between collision work and walking speed. Estimated preferred walking speed is strongly correlated to collision work with no significant difference between patients with PAD and controls.

CONCLUSIONS

Healthy, older subjects are an appropriate model to study collision work outcomes in comparison to patients with PAD. This allows for appropriately powered subject recruitment, and creates a wider impact for exoskeleton research dedicated to collision work. This study showed similar amounts of energy dissipated as collision work as compared to push-off creating another design parameter for improving walking efficiency through application of exoskeletons. These analyses also showcase the importance of maintaining a consistent walking speed when assessing the walking performance outcome measures for an exoskeleton device.

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A THERMOGRAPHY-BASED ANALYSIS OF FOOT TEMPERATURE DURING LOCOMOTION

Greg Faber[1], Kota Z Takahashi[1], & Andrew Kern[1]
Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: gfaber@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: [(3) **Poster Only**]

INTRODUCTION

Local aberrations in foot temperature is potentially damaging to soft tissue, and may lead to development of wounds or loss of function [1]. Normally, vascular flow maintains homeostasis and limits local temperature excursion. However, at-risk populations including those with altered blood flow to their extremities, such as individuals with peripheral artery disease or astronauts following return to earth may experience larger-than-normal foot temperature fluctuations and corresponding soft tissue damage [2]. A standardized protocol for measuring local foot temperature has yet to be established. To better understand risk of damage, particularly in terms of local temperature fluctuations, it is necessary to develop a validated and repeatable methodology for measuring regional foot temperature, and to understand these local temperature changes in a healthy population.

The purpose of this study is to develop and validate a methodology for the acquisition, and analysis of thermography images of the foot's plantar surface taken by an infrared thermal camera (FLIR T540sc, FLIR Systems, Wilsonville, OR). Infrared imaging will be validated using contact thermocouples. This methodology will be performed on normal healthy adults, walking over ground to establish repeatability of our standardized method, and how a healthy foot temperature fluctuates in normal adults.

We predict a strong correlation between contact probe and infrared thermal measurements. Additionally, we hypothesize that foot temperature measurements performed with our standardized methodology, will have greater reliability than those taken with a manual selection of foot regions.

METHODS

In this study, foot temperature data will be collected on 10 human participants before, during, and following a 30 minute track walking session. Prior to walking subjects will rest for 20 minutes to allow temperature to reach a normal state. A thermal image of the plantar surface of the feet will then be acquired.

Following baseline collection, the subjects replace their shoes, and walk for two laps around an indoor track at 1.25 m/s (~5 minutes). Consistent walking speed will be enforced by trained study personnel guiding the subject and maintaining timing using a stopwatch, and pre-defined distance markers. A thermal image of their feet will be acquired after every pair of laps. This process will be completed six times for a total of 30 minutes of walking.

Upon the completion of walking, subjects will remove their shoes and temperature behavior of their foot will be recorded when at rest. A sequence of time-lapse images (30 second intervals) will be acquired for a duration of 20 minutes.

Thermal images will be analyzed using two methodologies: 1) manual selection of foot regions via FLIR Research IR software, 2) semi-automated selection of foot regions using purpose written MATLAB software (Mathworks, Natick, MA) used to standardize foot thermography evaluation (**Fig. 1**). Foot regions identified will include: Hallux, MTP joints, Arch, Lateral Midfoot and Heel. Four investigators will evaluate thermal results for all subjects.

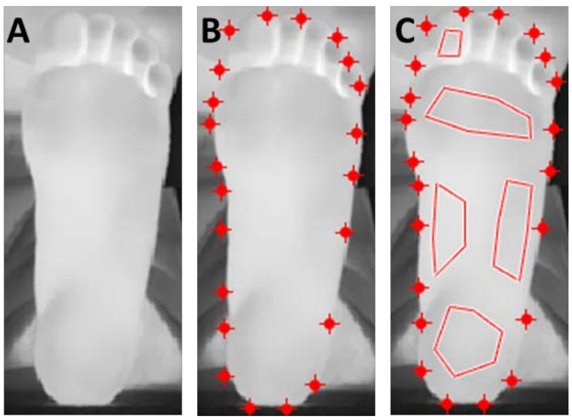

Figure 1: Semi-automated method of segmenting foot and identifying biomechanically relevant regions of interest. **A)** An individual foot is identified on the image. **B)** The boundary of the foot is segmented using a minimum-cost graph cut. **C)** Biomechanically relevant regions selected using an atlas-based approach.

Inter-rater reliability, and intra-class correlation will be computed for both the traditional, and the semi-automated methods to determine the repeatability of each technique. The validity of thermal imaging will be established by comparing regional contact probe data with thermal imaging.

RESULTS AND DISCUSSION

Data collection and processing is currently ongoing. We anticipate that the results of this study will provide a validated software for reproducibly measuring regional temperature changes on the plantar surface of the foot, along with a baseline knowledge about the thermal properties of the feet of healthy individuals.

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Induced stress during dual task improved secondary task performance at the sacrifice of primary task performance

Farahnaz Fallah Tafti[1], Jennifer M. Yentes[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
Email: ffallahtafti@unomaha.edu

Presentation Preference: [**Poster** or **Podium**]

INTRODUCTION

Doing multiple tasks at the same time is one of the inevitable situations that occurs frequently during our daily activities. Dual-task (DT) interference may have a detrimental effect on both tasks' performances [1, 2]. Several factors such as pathological conditions, aging process, and even stress may be able to affect DT performance [3], and identifying the possible effects are still under investigation. This research investigated the effect of mental stress on DT performance in healthy young adults. In this study, DT included standing while completing a secondary motor task (wire maze) with the upper extremity. Stress was induced mentally through a loud noise (buzzer). The aim of this study was to monitor perceived stress during DT, using a visual analog scale, and investigate how induced stress affects DT performance.

METHODS

Eighteen healthy young participants, (24.76±3.56 years; 68.85 ±11.85 kg; 1.72±0.07 m) without any respiratory, neurological, or musculoskeletal disease that would cause abnormal postural control or breathing, were recruited to this study. Participants were asked to perform single task (ST, no secondary task) and DTs (wire maze with or without buzzer) randomly while standing on a firm surface. The wire maze device was composed of a metal wire path (maze) and a single ring, held in one hand, which was passed through the wire maze. Participants were asked to prevent the contact of the maze and a metal ring.

A visual analogue scale of subjective perceived stress was used after each trial. Subjects were asked to rate their level of stress while doing each trial. Scores ranged from 1 to 10 with 10 representing the highest level of stress. The number of times the subject touched the metal ring to the wire maze was recorded as the number of errors. Ground reaction force (GRF) sample entropy (SampEn) in anterior posterior (AP) and mediolateral (ML) directions during standing was calculated to measure postural control regularity [4].

To determine the effect of mental stress, one-way repeated measures ANOVAs were used to compare perceived stress, wire maze errors, and postural control during the three conditions (ST, DT with buzzer, and DT without buzzer). The significance threshold was set at $\alpha=0.05$.

RESULTS AND DISCUSSION

Perceived stress was significantly lower during ST compared to DT with (p=0.001) and without buzzer (p=0.007) conditions. Wire maze errors were significantly higher during DT without the buzzer compared to the buzzer DT condition (p<0.0001) (Figure 1). GRF SampEn was more irregular during ST compared to DT with and without the buzzer in both the AP and ML directions (p=0.02, p=0.001, respectively in AP) & (p=0.004, p<0.0001, respectively in ML). Thus, subjects were able to perceive an increase in mental stress across conditions; however, the increase in perceived stress led to less errors in wire maze performance during the most stressful condition. This means buzzer feedback could decrease the errors of secondary task by increasing the participant's caution. Further, the addition of a secondary task increased the regularity of GRF in both directions, which might be due to more automatic GRF and less flexible postural control.

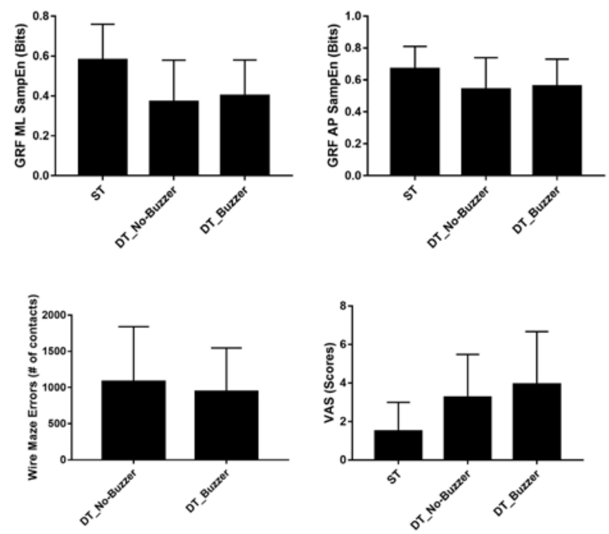

Figure 1: GRF SampEn in the ML (top left) and AP (top right), wire maze errors (bottom left), and perceived stress (scores 1-10) (bottom right)

CONCLUSIONS

The presence of DT and mental stress increased the regularity of GRF, while wire maze errors were reduced despite an increase in perceived stress. Induced stress during dual task caused a cost for postural control, yet a benefit for wire maze performance, indicating task prioritization under stress. In the future studies, identifying the effect of different stressors on DT performance, have potential to provide additional information about the mechanism underlying attentional theory.

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UNCONTROLLED MANIFOLD ANALYSIS OF GAIT VARIABILITY IN YOUNG ADULTS WITH SPASTIC DIPLEGIA

Kostas Gianikellis[1], Juan F. García-Vázquez[1,2], Andreas Skiadopoulos[3], Miguel Rodal[1], Rafael Gutiérrez-Horrillo[1].
[1] BioẼrgon Research Group, University of Extremadura, Cáceres, Spain.
[2] FREMAP, Mutual Funds for accidents at work and occupational illness associated with the Social Security nº 61, Spain
[3] Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA .
Email: kgiannik@unex.es
Presentation Preference: (2) Podium Only

INTRODUCTION
Stabilization of the head is the dynamic process of maintaining a position of equilibrium of the same in space [1]. It has been argued that postural control during gait depends to great extent on head stability [2-3]. Therefore, the research goal of this study was to analyze the stability of the position of the head during the heel strike and toe-off events of the gait cycle in person with spastic diplegia.

METHODS
Nine patients with spastic diplegia (6 males, 3 females; age: 17.4 ±4.2 yrs; mass: 52.3 ± 13.6 kg; height: 159.1 ± 15.4 cm) participated in the study after provided informed consent approved by the University of Extremadura research committee. Each patient performed 10 repeated single walking trials on a 7 m walkway at self-selected speed. Full body kinematics were collected and processed using a Simi motion capture system (100 Hz, eight-camera Simi Reality Motion Systems, GmbH, Germany) and low-passed filtered using residual analysis [4]. The methodological approach of the uncontrolled manifold hypothesis (UCM) has been applied to separate multi-joint variance into the variance that stabilize head posture (V_{UCM}) and the one that destabilizes it (V_{ORT}) (Figure 1) at the heel-strike and toe-off events of the gait cycle. The synergy index (V_{UCM}/V_{ORT}) was used to quantify whether joints formed synergies to stabilize the head at heel-strike and toe-off events. A factorial ANOVA was conducted to analyze whether movement plane (sagittal and frontal) and body side (left and right) affect synergies. According to the UCM hypothesis a synergy is formed when the synergy index is positive, with higher values means stronger synergy.

RESULTS
For the sagittal plane the synergy index was the following: right heel-strike (-0.023 ± 0.28), left heel strike (0.036 ± 0.39), right toe-off (-0.0067 ± 0.3) and left toe-off (-0.14 ± 0.2). For the frontal plane, the synergy index was the following: right heel-strike (0.25 ± 0.41), left heel-strike (0.14 ± 0.23), right toe-off (0.5 ± 0.4), and left toe-off (0.16 ± 0.23). The ANOVA indicated a significant effect of the plane factor ($p < 0.01$). Sidak's post-hoc analysis indicated significant differences between the sagittal and frontal plane, but for the right body side ($p<0.001$).

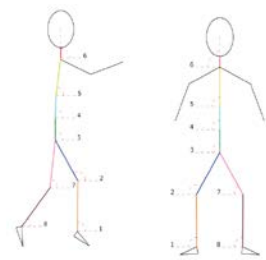

Figure 1: Stick figure showing the how segmental angles were computed in the sagittal and frontal plane (1 & 8: shank; 2 & 7: thigh: 3: pelvis; 4: abdomen; 5: thorax; 6: head).

DISCUSSION AND CONCLUSION
The quantification of the kinematic synergies allowed the description, analysis and evaluation of movement control during gait in patient with spastic diplegia. The analysis of the results revealed significant differences regarding the motor control process for the sagittal and frontal planes, that is in line with previous studies [5]. The results could be very relevant for planning the therapeutic approach and monitoring the clinical evolution in people with spastic diplegia. This could offer to human movement specialists a window onto the functioning of the complex control mechanisms that the central nervous system use to coordinate the multiple degrees of freedom during gait.

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Table 1: ANOVA table for synergy index

ANOVA	Sum of squares	DOF	Mean Squares	F (DFn, DFd)	P value
Interaction	0.1549	1	0.1549	F(1,68)=1.47	P=0.230
Plane	1.584	1	1.584	F(1,68)=15.03	**P<0.001**
Side	0.3147	1	0.3147	F(1,68)=2.986	P=0.089
Residual	7.167	68	0.1054		

VARIABILITY IN DIFFERENT MINIMALLY INVASIVE PROCEEDINGS

Kostas Gianikellis[1], Rafael Gutiérrez-Horrillo[1], Miguel Rodal[1], Juan A. Sánchez-Margallo[2] , Francisco M. Sánchez-Margallo[2] & Andreas Skiadopoulos[3]
[1] BioẼrgon Research Group, University of Extremadura, Cáceres, Spain.
[2] Jesús Usón Minimally Invasive Surgery Center, Cáceres, Spain.
[3] Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
Email: kgiannik@unex.es
Presentation Preference: (2) **Podium Only**

INTRODUCTION

Laparoscopic surgery (LAP) provides multiple advantages for the patient [1], but it entails certain inconveniences for surgeons such as the limited degrees of freedom due to the use of fixed surgical ports. This restriction of movements leads to an increased incidence of static postures of head and torso and adoption and maintenance of awkward body postures for long periods of time [2] what increases the possibilities of muscle fatigue and musculoskeletal pathologies [3]. Towards this end, the uncontrolled manifold hypothesis (UCM) provides a quantitative approach to analyze the influence of imposed constraints, e.g. workplace layout and instruments design, on the postural strategy that surgeons choose to accomplish surgical tasks. In this study, we examine the effect of two different laparoscopic approaches on redundancy exploitation for head movement stabilization.

METHODS

The study sample was eight experienced surgeons in LAP and LESS (laparoendoscopic single site) approaches. Two HD video cameras with a sampling rate of 50 Hz were used to record surgeons' posture during surgical activities. The recorded videos were processed using the MaxTRAQ software (Innovision-Systems, USA). 3D coordinates were obtained for a total of 40 events (N = 40), an event every 15 sec of surgical activity. The UCM hypothesis allowed to map the variance of three individual joint angles $\theta^t = (\theta_1^t, \theta_2^t, \theta_3^t)^T$, with t = 1, 2…, N, onto the head position variance, and to separate the combinations of θ^t that are equally able to stabilize head position, within an acceptable margin of error, for those θ^t combinations that are irrelevant of the ongoing task . A simple geometrical model that links the joint configuration of the left and right upper-body with head position in a sagittal plane was developed (Fig. 1). The head coordinate (Y) is a certain function of positioning angles θ^t: $Y_\theta = L_1 cos\theta_1^t + L_2 \cos(\theta_1^t + \theta_2^t) + L_3 \cos(\theta_1^t + \theta_2^t + \theta_3^t)$. The posture of the head was defined with respect to the trunk.

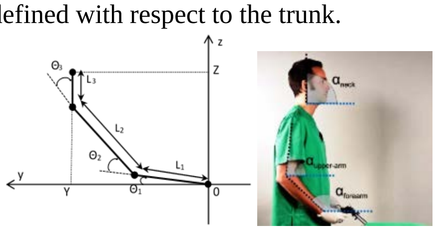

Figure 1. Three-link geometrical model in a sagittal plane used in the UCM analysis**.** From the origin, each circle shows the wrist, elbow, shoulder joint and vertex, whereas θ_n (n = 1, 2, 3) shows each joint angle, and L_n (n = 1, 2, 3) shows the forearm, upper-arm length, and neck-head length.

RESULTS

The results of the UCM analysis showed a positive synergy index indicating that the covariation of the upper-limb joint angles stabilizes the head posture of the surgeons in the anterior-posterior direction. Even though the synergy index takes different values between the LAP and LESS approach (Fig 2), there was not a statistically significant difference in the synergy index between the LAP and LESS approach of both the left ($t_{(7)}$ = 1.76, p = 0.12) and right joint spaces ($t_{(7)}$ = 0.127, p = 0.902).

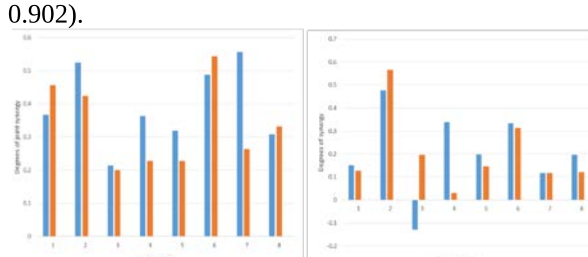

Figure 2: The degree of synergy index for the LAP and LESS approach for the UCM of the left and right side joint spaces.

CONCLUSIONS

The 3D kinematics analysis gave information regarding the head posture adopted by the surgeons with respect to the trunk and how it varies during surgical activities. Furthermore, surgeon's upper-body joint variability was quantified using the framework of the UCM hypothesis, allowing to separate the combination of joint angles that were equally able to stabilize head mean posture on sagittal plane for those solutions that were destabilized head mean posture. The results showed that the underlying framework was able to quantify surgeons' motor variability, providing inspiration for new human-machine interaction designs, as well as more targeted ergonomics assessments.

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ESTIMATING VARIATIONS OF METABOLIC COST WITHIN THE STRIDE CYCLE DURING LEVEL AND UPHILL WALKING

Arash Mohammadzadeh Gonabadi, Prokopios Antonellis, & Philippe Malcolm
Department of Biomechanics and Center for Research in Human Movement Variability,
University of Nebraska at Omaha, Omaha, NE, USA
email: amgonabadi@unomaha.edu, web: http://coe.unomaha.edu/brb

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INTRODUCTION

Using modern motion capture systems, we can measure kinematics, kinetics, and EMG at hundreds of frames per second, which allows us to plot the time profile of these variables within the stride cycle. However, with indirect calorimetry, we can only measure the average cost of a stride cycle which prevents us from identifying which part of the gait cycle causes increased metabolic cost in patient populations.

Recent simulation methods allow estimating the time profile of metabolic cost within the stride cycle [1], [2]. Umberger [1] developed equations that allow estimating the time profile of metabolic cost using electromyography-driven musculoskeletal simulations [1]. Roberts et al. [2] developed another set of equations that allow estimating the time profile of metabolic cost using only joint moments and angular velocities.

This study aimed to compare the estimations of the time profile of the metabolic cost of two simulation methods for level and uphill walking.

METHODS

We used kinematic, kinetic and electromyography data from level and uphill walking from one participant [3]. We estimated the time profiles of metabolic cost using the muscle-level metabolic model of Umberger [1] by entering electromyography and kinematic data into a musculoskeletal simulation (OpenSim) to generate estimates of muscle-level mechanics [4]. We also estimated the time profile of metabolic cost based on the joint moments and joint angular velocities using the method of Roberts et al. [2].

RESULTS AND DISCUSSION

Both methods show a phase of high metabolic cost in the first 10% of the gait cycle. The Umberger [1] method reveals another phase with a high metabolic cost during the second half of stance whereas the Roberts et al. [2] method shows a phase with high metabolic cost in early swing phase. This could be because both methods use different data (muscle mechanics versus joint mechanics) (Fig. 1).

Both methods estimate an increase in metabolic cost with uphill walking which is consistent with indirect calorimetry measurements. The method from Roberts et al. [2] underestimates the metabolic cost increase more than the method from Umberger [1]. This could be because the method from Roberts et al. [2] was developed with data from walking at different speeds and not with data from walking on different slopes (Fig. 2).

CONCLUSIONS

There is no experimental measurement of the time profile of metabolic cost that allows identifying which of the two estimation methods is more accurate. Experiments with robotic devices that allow to alter metabolic cost during specific phases of the gait cycle [5], [6] could provide new insights. The fact that both methods show moderate similarity and are able to detect the increase in metabolic cost during uphill walking suggest that they could be useful as an input for optimization methods of assistive devices (e.g., exoskeletons).

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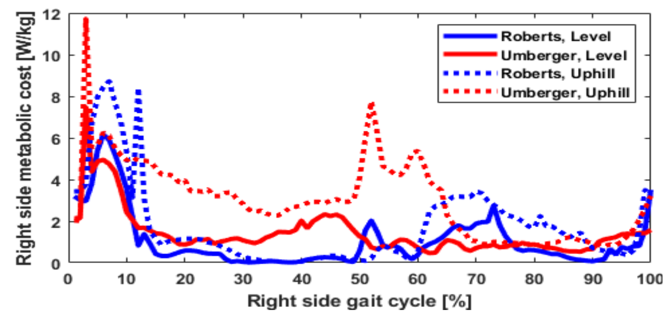

Figure 1: Estimation of the time profile of metabolic cost with Umberger [1], Roberts et al. [2] methods.

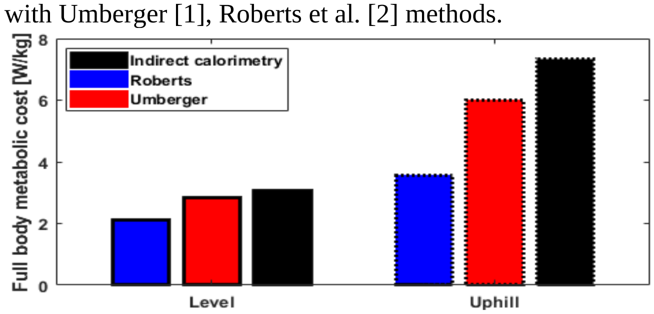

Figure 2: Average of metabolic cost from Umberger [1], Roberts et al. [2], and indirect calorimetry [3].

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FOOT THERMAL RESPONSE TO SHEAR MAGNITUDE DURING CURVED-PATH WALKING

Angel E. Gonzalez[1], Andrew M. Kern[1] & Kota Z. Takahashi[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE, USA
email: agonzalez@unomaha.edu

Presentation Preference: [(3) **Poster Only**]

INTRODUCTION

Foot temperature has been demonstrated to significantly increase after walking within healthy individuals [1]. Though this may not be a problem for healthy individuals, it can affect clinical populations (e.g. individuals with neurological or vascular impairment) who demonstrate a difference in foot temperature between affected and non-affected limb [2]. The primary mechanism for observed increases in foot temperature is currently unknown.

Mechanical forces on the foot may be a causative factor in plantar surface temperature increases. Shear force in particular, may have an influence on foot temperature fluctuations [2]. In fact, a significant relationship exists between peak shear stress and foot temperature within neuropathic individuals [3]. However, study design limitations of previous work has prevented application of these results in a broader population.

One method of controlling the shear forces at the foot is through turning gait. Curved path walking induces higher magnitudes of shear compared to straight line walking [4]. As the degree of turning increases (smaller radius), the shear forces are expected to increase to adjust the bodies center of mass direction. Therefore, if consistent walking speed is fixed, shear will increase proportionally to the reduction in curvature radius.

The purpose of this study is to investigate the thermal response of the foot to different levels of shear force during curved-path walking. Curved path walking of varying radii will be used to induce higher shear forces in the foot. To minimize the possibility of cancellation of opposing shear forces (from the forefoot and hindfoot) without the use of a shear detecting force plate, toe walking will be utilized. We hypothesize that foot temperature increase will be related to greater shear (higher magnitude of shear with smaller radius). We also predict that foot temperature will be greater on the external limb compared to the internal limb, as it will experience greater shear forces.

METHODS

The study will analyze the thermal response of the healthy human foot to shear forces in a single data collection. Within this collection, three five-minute trials will be performed, in which the participant will walk on circular paths of three different radii. Each trial will be performed in a randomized order by walking barefoot in a circular path over a force plate recorded by a motion capture system. The radius for each trial will be set at 1.0 m, 1.5 m, or 2.0 m. Walking speed will be controlled by using a speed light gate timing system with a speed of 1.25 m/s and a permissible deviation of ± 0.05 m/s (Dashr Elite Kit, Lincoln, NE).

Pre-walking temperature measurements will be taken prior to the first walking condition and in between each condition. The participant temperature at the forefoot segment (e.g. 1st and 5th metatarsal and hallux) will be taken by having the subject lay down on a table in a supine position. Temperature will be measured using a thermal imaging camera (FLIR, Wilsonville, OR). Participants will rest for a minimum of 30 minutes prior to walking and in between each trial to reach thermal equilibrium.

Each participant's force and marker data will be processed using Cortex software (Motion Analysis Corporation, Rohnert Park, CA). Visual3D software (C-Motion, Germantown, MD) will be used to analyze the difference in shear force between different radii as well as differences between external and internal limbs. The mediolateral and anteroposterior component of shear will be analyzed in addition to the resultant shear component. Temperature will be analyzed using FLIR ResearchIR software. Temperature increases will be compared between individual foot regions to determine the relative sensitivity of each to shear loading.

ANTICIPATED RESULTS

It is anticipated that shear forces will increase for a smaller radii. Higher shear forces are expected to cause an increase in foot temperature (Figure 1).

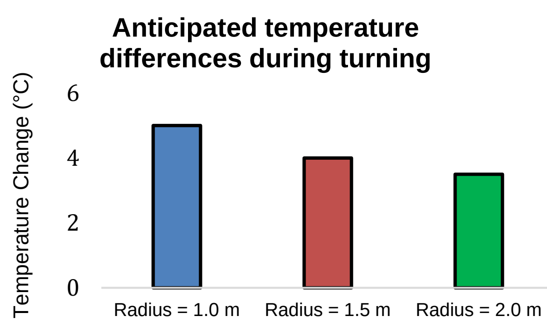

Figure 1: A tighter radii results in a higher temperature change. This trend would be in support our first hypothesis meaning that shear is a good predictor of foot temperature increase.

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THE EFFECTS OF JOINT ANGLE VARIABILITY ACROSS TERRAINS ON KNEE ARTHROPLASTY SATISFACTION

Tyler Hamer, Abderrahman Ouattas, Katlyn Nimtz, & Brian A. Knarr
Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
Email: thamer@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/
Presentation Preference: (3) **Poster Only**

INTRODUCTION

Total Knee Arthroplasty (TKA) procedures are quickly becoming one of the most prevalent surgeries in the United States, with roughly 700,000 performed per year [1,2]. While pain and health-related quality of life are often improved post-surgery, recent studies have shown that up to 30% of patients are not satisfied with their TKA outcome [3]. Asymmetric gait mechanics have been identified in TKA patients post-surgery, however, little information is known regarding how this asymmetry manifests itself during real-world activities [4-6]. The effect of different terrains on local joint stability during walking in TKA patients has yet to be examined, especially in the realm of nonlinear analysis. **Therefore, the purpose of this study is to determine the relationship between walking variability and clinical measures in TKA patients.**

METHODS

Subjects: Seven TKA participants (Age: 64.14 ± 10.34, BMI: 32.34 ± 6.31) were recruited for this study. All subjects had undergone a unilateral TKA procedure (Mean: 9 months prior) and had no previous history of TKA revision surgery. ***Functional & Clinical Testing:*** All subjects completed three walking trials on three different surfaces: an indoor track, an outdoor paved surface, and an outdoor unpaved surface. Subjects were asked to walk as much distance as possible for 6 minutes (track) and 3 minutes (paved, unpaved). The Knee Society Scoring System (KSSS) was given to address participant's satisfaction with their TKA procedure. The KSSS was developed and validated to address the expectations, physical activity, and satisfaction of a more diverse population of TKA patients. ***Data Analysis:*** A custom MATLAB code that uses the Wolf algorithm [7] was used to calculate the Lyapunov Exponent (LyE). Linear regressions were performed to measure the relationship between stride variability and satisfaction.

RESULTS

Variability, as determined by the Lyapunov exponent, increased as the walking surface was less consistent (track<paved<unpaved) (Figure 1). Initial findings identify a possible relationship between stride variability and satisfaction for the TKA limb on the involved limb, with the relationships approaching significance ($p < 0.1$) on the track and unpaved surfaces (Table 1). Relationships were the strongest on the unpaved (R^2 = .5002) surface. The highest KSSS score belonged to the most variable subject, while the lowest KSSS score belonged to the least variable individual.

	Track	Paved	Unpaved
Involved	0.45*	0.34	0.5*
Uninvolved	0.18	0.31	0.39

Table 1: R^2 values for each limb across terrains comparing KSSS and LyE values. * indicates p <= 0.1

DISCUSSION

KSSS scores showed a moderate relationship to stride-to-stride variability within the knee. The most satisfied patient exhibits the highest amount of variability, and the least satisfied having the lowest LyE on all but the unpaved terrain, yet no further trends are apparent within the rest of the subject population. Preliminary data shows that there are trends between satisfaction and stride-to-stride variability, and we expect this relationship to become stronger with additional participants.

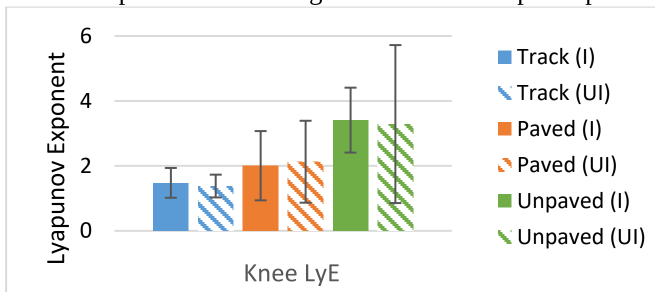

Figure 1: LyE values across terrains for the Involved (I) and Uninvolved (UI) limbs

CONCLUSION

Increases in variability across terrains suggest that less homogenous terrain calls for different walking strategies to overcome obstacles. Initial findings identify possible relationships between stride variability and TKA satisfaction on the track and unpaved surfaces, with the strongest relationship being on the unpaved surface. Through this, we believe that our least and most variable surfaces may give the most insight into the relationship between satisfaction and variability. Lastly, the highest KSSS score resulted in the highest stride-to-stride variability across all terrains while the lowest KSSS score resulted in the first, second, and third lowest variability measure on the track, paved, and unpaved surfaces respectively. We suspect that people who demand less of their TKA are more satisfied than those who require more of their knee and thus, are more critical of knee performance. Noting our initial findings, our hypothesis suggest that we move out of the clinical setting to the outside environment, where trends between walking variability and satisfaction are developing. Ultimately, accrual must be continued within the current study to fully examine the trends between walking variability and satisfaction.

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FORCE, DISPLACEMENT, AND WORK PROFILES OF COMBINED FOOT AND ANKLE STRUCTURES DURING TYPICAL WALKING

[1] Erica A. Hedrick, [2] Steven J. Stanhope, [1]Kota Z. Takahashi
[1] Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2] Department of Kinesiology & Applied Physiology, University of Delaware, Newark, DE USA
email: ehedrick@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: **Poster Only**

INTRODUCTION

A comprehensive understanding of combined human foot and ankle function can drive innovations and development of ‘bio-inspired’ wearable devices, such as prostheses, and exoskeletons. A recent study of human walking found that the biological foot-ankle structures produce near equal magnitudes of negative and positive work [1]. A generalized technique to synthesize mechanics of the foot-ankle structures is warranted, such as quantifying the total force, displacement, and work. For example, displacement of the center-of-pressure relative to the shank during stance in normal walking has yielded novel approaches for prescribing prosthetic foot-ankle components that attempts to preserve a natural ‘roll-over shape’ [2]. Yet, to prescribe elastic devices that can store and return mechanical energy, a comprehensive knowledge regarding the force, displacement, and work of the foot-ankle system is needed.

The purpose of this study was two folds. First, we aimed to quantify the total force, displacement, power, and work of the combined foot and ankle structures in normal walking. Second, we tested the hypothesis that subject’s body height and mass are strong predictors for the individual variability of force, displacement and work. This knowledge would facilitate creation of a regression-model that may be used to customize unpowered wearable foot-ankle devices.

METHODS

Eleven healthy subjects (6 females, 5 males, ages 24.2 ± 2.9 yrs, height 1.72 ± 0.08m, and body mass 75.3 ± 21.8 kg) participated in a fully-instrumented gait analysis. The subjects walked barefoot at four velocities: 0.4, 0.6, 0.8 and 1.0 statures/s. The data from one walking velocity (0.8 statures/s) were included in this abstract. Data were processed and analyzed using Visual3D software (C-Motion Inc., Germantown, MD). A second-order dual-pass low-pass Butterworth filter (6Hz for kinematic data and 25Hz for kinetic data) was applied to the raw data.

To quantify force and displacement relative to the shank during stance, we transformed the ground reaction force and center-of-pressure (COP) data from the laboratory coordinate system to the shank’s coordinate system (SCS), respectively [2]. To quantify mechanical power of the combined ankle and foot systems, we used a unified deformable segment analysis [3]. To quantify mechanical work, we integrated power over time.

Multiple regression analyses were performed to determine if body height and mass were related to measures of force, displacement and work. Specifically, we analyzed the peak force and total displacement in the anterior-posterior (A-P) and superior-inferior (S-I) axes of the SCS.

RESULTS AND DISCUSSION

The combined ankle and foot structures produced slightly greater magnitude of negative work (-16.18 ± 8.05 J) than positive (13.14 ± 4.57 J), resulting in slight net negative work (-3.05 ± 5.63 J). Body height and body mass accounted for 66.1% of the variance in positive work ($p=0.013$) and 85.5% of the variance in negative work ($p<0.001$).

The COP displaced in the superior direction in the presence of a superior-directed force through most of stance, which is analogous to a spring being compressed longitudinally (i.e., foot-ankle structures performing negative work) (Figure 1). During terminal stance, the COP displaced in the inferior direction in the presence of a superior-directed force, which is analogous to a spring recoiling after being compressed (i.e., foot-ankle structures performing positive work). Body height and body mass explained 67.9% of the variance in the peak force along the A-P axis ($p=0.011$) and 99% of the variance in the peak force in the S-I axis ($p<0.001$).

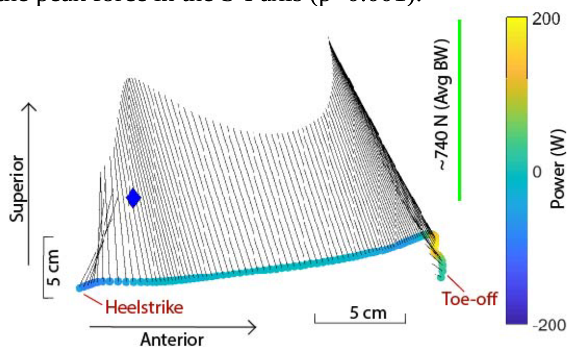

Figure 1: Displacement, force and power of the combined ankle and foot structures during stance phase. The colored circles indicate displacement of the COP in the shank coordinate system (SCS), and the colors of the circles represent power intensity at each point in stance. Black lines represent the magnitude of the ground reaction force in the SCS. Blue diamond represents the location of the ankle joint center in the SCS.

CONCLUSIONS

The force, displacement, and work characteristics of combined foot and ankle structures in normal walking are largely predicted by body mass. These findings can inform the design and customization of unpowered foot-ankle devices that can emulate biological functions during walking.

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EFFECT OF MOTION CAPTURE SAMPLING FREQUENCY ON FRACTAL FLUCTUATIONS DURING TREADMILL WALKING

Alan Hoffmann[1], Shane Meltz[2], Vivien Marmelat[2]
[1]College of Arts and Science, University of Nebraska at Omaha, Omaha, NE USA
[2]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: sc2d.labuno@gmail.com

Presentation Preference: [Please indicate (3) **Poster Only**]

INTRODUCTION

The temporal organization of stride-to-stride fluctuations during steady-state walking can reveal important information about locomotor control [1]. A dominating method to analyze stride-to-stride fluctuations is the detrended fluctuation analysis (DFA) [2]. In an effort to standardize DFA processing, researchers determined some gait-specific parameters required to produce accurate DFA results. In the context of locomotion, it is important to consider the parameters underlying data acquisition and pre-processing before applying DFA. In particular, motion capture systems are typically used to record gait during treadmill walking, but there is no consensus on the most appropriate sampling frequency necessary and sufficient to reliability apply DFA. The goal of this study was to determine if motion capture sampling frequency and downsampling procedures affect DFA from spatiotemporal variables.

METHODS

Seventeen young adults (23.9 ± 2.7 years, 7 females) were recruited through convenience sampling to participate in the study. Participants were affixed with 11 retroreflective markers on anatomical landmarks to track their lower limb motion while walking in three conditions (random order) on a motorized treadmill at self-selected, preferred speed. Marker motion was captured through 8 infrared cameras (Vicon, Centennial, CO) at different sampling frequency for each condition: 60 Hz, 120 Hz and 240 Hz. Gait events were extracted from the original raw data in the 240, 120 and 60 conditions. We also down-sampled the raw data from the 240 condition to 120 Hz and 60 Hz (i.e., 240ds120 and 240ds60 conditions, respectively). In this study, we focused on the following six spatiotemporal variables from each of the five conditions: step and stride time, length and speed, from left and right sides. Further analyses considered 678 step or stride intervals for all time series for all participants. We calculated the mean, standard deviation (SD), coefficient of variation (CV) and scaling exponent (DFA) from each spatiotemporal variables.

One-way repeated measures ANOVAs were performed 1) between conditions 240, 240ds120, and 240ds60, and 2) between conditions 240, 120, and 60, on right side measures (mean, CV and DFA) for each of the six spatiotemporal variables. Post-hoc analysis entailed Tukey's multiple comparison's tests. For each spatiotemporal variables, ICC estimates and their 95% confident intervals were calculated using SPSS statistical package version 23 (SPSS Inc, Chicago, IL) based on a single-measurement, absolute-agreement, two-way mixed-effects model (ICC 3,1) to determine the reliability of mean, CV and α-DFA. We compared 1) conditions 240, 240ds120 and 240ds60, and 2) conditions 240, 120 and 60. The reliability was graded based on the lower 95% CI values, with values less than 0.50 indicating poor reliability, values between 0.50 and 0.75 indicating moderate reliability, values between 0.75 and 0.90 indicating good reliability and values above 0.90 indicating excellent reliability [27-28]. Level of statistical significance for every test was set at a p-value < 0.05.

RESULTS AND DISCUSSION

There was no statistical significant differences between conditions 240, 240ds120 and 240ds60, for any measures of any spatiotemporal variables ($p>0.05$). The ICCs revealed excellent absolute agreement between the mean for all spatiotemporal variables. For CV, the reliability was poor to excellent for step length, moderate to excellent stride length, stride time and step speed, good to excellent for stride speed and excellent for step time. For α-DFA, the 95% confidence interval revealed moderate to excellent reliability for step length, step time, stride time, step speed and stride speed, and good to excellent for stride length. There was no statistical significant differences between conditions 240, 120 and 60, for any measures of any spatiotemporal variables ($p>0.05$). The ICC revealed good to excellent reliability for mean of step length and step speed, and excellent reliability for all other spatiotemporal variables. The reliability of CV was poor to good for stride length, step time, stride time and stride speed, and moderate to excellent for step length and step speed. In contrast, for α-DFA the 95% confidence interval revealed poor to moderate reliability for step length, step time, step speed and stride speed, and poor to good for stride length and stride time.

CONCLUSIONS

Our main findings are that i) in general, mean, CV and α-DFA values of all spatiotemporal variables were similar between conditions, whether the data was downsampled or collected at different sampling frequencies, ii) α-DFA values were very reliable between original and downsampled spatiotemporal variables, iii) α-DFA values were not reliable between conditions using different sampling frequencies, iv) α-DFA from stride intervals were more reliable than step intervals.

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MAXIMIZING ORTHOSIS STIFFNESS AND LEVERAGE ISOLATES CONTROL OF ANKLE MOTION

Christopher Hovorka[1], Geza Kogler[2], Young-Hui Chang[2] & Robert Gregor[3]
[1]Department of Rehabilitation Science and Technology, University of Pittsburgh, Pittsburgh, PA USA
[2]School of Biological Sciences, Georgia Institute of Technology, Atlanta, GA USA
[3]Division of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA
email: chovorka@pitt.edu

Presentation Preference: **Poster** or **Podium**

INTRODUCTION

Despite their prevalence of use, motion control of ankle foot orthoses (AFOs) is subjectively characterized [1] and lacks rigorous evidence based on uniform testing and analysis [2]. Orthoses are loosely described as force transmission devices to control motion, but there is a lack of evidence to confirm this notion. Therefore, the purpose of this investigation was to clarify a general principle of orthoses, that maximizing stiffness and leverage will maximize a three-force system to produce maximum motion control [3]. To test this principle, we quantified motion control of a novel AFO maximizing stiffness and leverage and predicted that the AFO in ankle STOP condition will decrease ankle motion compared to AFO in ankle FREE and CONTROL (no AFO) conditions during walking.

METHODS

Fourteen healthy subjects (8 females, 6 males, age 21.04 ± 0.89 yrs, height 171.19 ± 4.11 m, mass 65.74± 4.72 kg) gave written informed consent to participate in a protocol approved by the Georgia Tech Institutional Review Board. A 3-D gait lab using six high speed cameras (Vicon, 120 Hz), 16 reflective markers taped to the lower limbs of subjects and a custom dual belt treadmill with imbedded force plates (AMTI, 1080 Hz) were used to collect joint motion, ground reaction forces and joint moments respectively during walking. Subjects walked at preferred speed (1.34±0.09 $m \cdot s^{-1}$) using an ankle foot orthosis-footwear combination (AFO-FC) in three walking conditions: CONTROL condition (bilateral footwear, no AFO), FREE condition (use of contralateral footwear with ipsilateral AFO-FC in a no constraint condition) and STOP condition (use of contralateral footwear with ipsilateral AFO-FC in a maximal constraint) (Figure 1). Footwear was designed to preserve rollover motion. All motion and force data in the sagittal plane were synchronized, filtered and time normalized to 100% of the gait cycle. Mean ankle joint angle and moments in each condition were analyzed using 95% confidence interval and a repeated-measures ANOVA with Bonferonni post-hoc comparison.

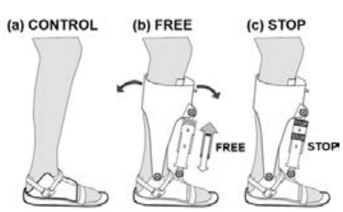

Figure 1. Ipsilateral ankle motion conditions. **(a)** No AFO (CONTROL) with footwear, **(b)** AFO FREE with footwear, **(c)** AFO STOP with footwear. AFO design maximizes stiffness and leverage using carbon composite, full shank and foot shells and linear bearing anchored 10 cm from ankle joint.

RESULTS AND DISCUSSION

Subjects exhibited decreased ipsilateral ankle range of motion to within 3.7±2.1° in STOP condition compared to 27.7±4.2° in CONTROL condition without the AFO (p=0.000) and 24.2±3.6° in FREE condition (p=0.091) and no difference in ankle moments (p>0.05). Unexpectedly, ankle motion and moments were no different between the three conditions on the contralateral leg (p>0.05) (Figure 2). Cadence was similar in CONTROL, STOP and FREE conditions (p>0.05). AFO-FC in STOP condition substantially limited motion during stance phase when the ankle experiences the greatest joint moments and is typically, where one might see lack of motion control. An explanation for the consistency in limited ankle motion in STOP condition despite considerable ankle torque is likely related to stiffness and leverage effectively mitigating forces between AFO and limb in a coupled three-force system.

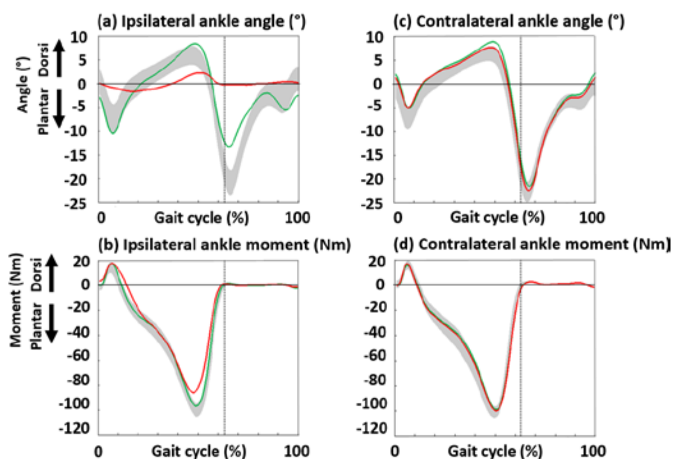

Figure 2. (a) Ipsilateral ankle angle (°) and moment (Nm) **(b)**, **(c)** contralateral ankle angle (°) and moment (Nm) (**d**). Data normalized to gait cycle (%) in CONTROL, FREE and STOP conditions during minute 4. A 95% confidence interval of CONTROL (gray), mean of FREE (green) and mean of STOP (red) for all 14 subjects. Toe off in CONTROL (vertical line).

CONCLUSIONS

Findings support a general principle that maximizing leverage and stiffness in AFO design produces maximum ankle motion control during walking. Surprisingly, motion control was isolated to the ipsilateral leg. Footwear used in combination with the AFO likely maintains rollover dynamics, which preserves full ankle range of motion on the contralateral leg.

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Cognitive Impairment Impacts Single and Dual Task Performance in Older Adults

Hyeon Jung Kim[1], Farahnaz Fallah Tafti[2], Jennifer M. Yentes[2], Julie Blaskewicz. Boron[1]
[1]Department of Gerontology, University of Nebraska at Omaha, Omaha, NE USA
[2]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
Email: hyeonjungkim@unomaha.edu
Presentation Preference: [**Podium or Poster**]

INTRODUCTION

Detection of cognitive impairment is important as older adults with decreased cognitive function can have a higher risk of falling [1]. Falls are an important public health concern. Additionally, completing multiple tasks simultaneously is considered a high cognitive load situation in older adulthood, and performance during such a situation can be indicative of fall risk, however, various tasks may have differential interference effects [2]. Thus, an individual with cognitive decline may have an increased risk of falls during high cognitive load situations. To detect mild cognitive impairment (MCI), the Montreal Cognitive Assessment (MoCA) has been used. A MoCA score lower than 26 indicates cognitive impairment [3]. Thus, the purpose of this study was to investigate walking and cognitive performance in older adults with high and low MoCA scores. A previous study demonstrated that an additional secondary task had a detrimental effect on mobility [4]. It was hypothesized that people with a low MoCA score would sacrifice walking performance to maintain their cognitive performance.

METHODS

Twenty-two healthy, older adult subjects (71±5 yrs; 8 males), able to walk 60 meters without an assistive device, were recruited from senior wellness centers in the community. Each subject was assessed with the MoCA; post hoc groups based on cognitive functioning were created: low MoCA score <26, and high MoCA, score ≥26. Subjects completed three trials: 1) cognitive task while seated (single task, ST); 2) walking only; 3) cognitive task while walking (dual task, DT) [5]. Walking was done on a self-paced treadmill. Category fluency was the cognitive task. Subjects received a category and were instructed to name as many as words within that category for 1 minute; a total of 3 categories were assessed over 3 minutes. The percentage of correct answers for each trial quantified cognitive performance. Walking performance was measured using step width mean and variability (i.e., standard deviation). Analyses controlled for age, BMI, education level, and number of prescription medicines. To compare performance between MoCA groups, 2x2 repeated measures ANCOVAs were conducted with cognitive task while seated (ST) vs. cognitive task while walking (DT) as a within subject condition for each dependent variable. Statistical significance level was α=0.05.

RESULTS AND DISCUSSION

The high MoCA group (n=8) had significantly better cognitive performance during DT compared to the low MoCA group n=12; p=0.03; Table 1). There was no main effect of trial nor interaction. Walking performance, as quantified by step width mean and variability, did not show any difference between groups or trials, nor was there a significant interaction. These findings are in opposition to our hypothesis, demonstrating that those with low MoCA scores would sacrifice cognitive performance to maintain walking performance during high cognitive load situations. To maintain stable walking, control of gait during dual tasking was assumed to be an additional cognitive load for people with a low MoCA score leading to competition for available brain resources and consequently deficits in gait. Step width was selected to quantify walking performance because it is a likely indicator of fall risk [6]. Those with increased fall risk would widen their base of support, step width, to increase stability while walking [6]. Although not significant, step width mean was narrower in the high MoCA group compared to the low MoCA group. The lack of significance was likely due to statistical power as a sample size analysis demonstrated that 16 per group would elicit statistical significance. Future studies should include a larger sample to determine if individuals with low MoCA scores change their walking performance to increase stability during high cognitive load situations.

CONCLUSIONS

As MoCA is a potential indicator of cognitive performance, older adults with better MoCA performance scored higher on the category task during both single and dual task conditions. However, walking performance did not differ between the two groups. Additional research in brain imaging would be beneficial to clarify the prioritizing mechanism as well as resource competition in older adults with cognitive impairments during dual task paradigms.

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Table 1: Mean (standard deviation) of single and dual task performance

	Category (%)		Step Width Mean (mm)		Step Width std (mm)	
	ST	DT	ST	DT	ST	DT
High MoCA (n=8)	92.3 (4.1)	93.1 (3.7)	158.4 (32.6)	155.8 (23.9)	19.0 (5.5)	22.0 (7.9)
Low MoCA (n-12)	92.0 (4.4)	89.1 (6.6)	158.6 (44.2)	161.6 (48.0)	21.7 (5.8)	21.9 (5.4)

Note: ST = single task; DT = dual task; std = standard deviation

DO FOOT BIOMECHANICS AFFECT PLANTAR TEMPERATURE IN PEOPLE WITH VASCULAR DISEASE?

Andrew M Kern[1], Iraklis Pipinos[2,3], Sara Myers[1,2], & Kota Z Takahashi[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]Nebraska and Western Iowa Veterans Affairs' Medical Center, Omaha, NE USA
[3]Department of Surgery, University of Nebraska Medical Center, Omaha, NE USA
email: andrewkern@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: [(3) **Poster Only**]

INTRODUCTION

Elevated temperature of the plantar surface of the foot may be harmful to soft tissue health and may lead to skin breakdown and eventual ulceration [1]. This is particularly important in patients with peripheral artery disease (PAD) and diabetic patients, who are at risk for damaging temperature changes and injury due to impaired blood flow, and vascular control in their feet [2].

Previous work has identified that walking increases foot temperature in both healthy individuals and those with diabetes [3]. It remains unclear to what extent foot temperature is influenced by mechanical deformation vs. altered vascular flow or other factors. During walking, the foot loses energy (producing negative net-work), which is likely dissipated into the plantar surface as heat. In individuals with normal physiology, this is counteracted by blood flow, which maintains homeostasis and regulates tissue temperature. However, if blood flow to the extremities is decreased or poorly regulated, larger temperature fluctuations, which are harmful to tissue health, may occur.

The purpose of this ongoing study is to investigate how foot biomechanics influence foot temperature during walking in PAD patients and patients with diabetes. It is expected that feet which dissipate more energy (negative net-work) will have larger increases in plantar surface temperature. Additionally, it is anticipated that patients with PAD/Diabetes will experience a larger temperature increase in their feet following walking.

METHODS

In this study, four groups of participants are recruited: healthy, PAD, diabetes and PAD+diabetes. All subjects are between the ages of 40 and 85 and capable of walking over-ground and on a treadmill for durations of 5 minutes or greater.

At the start of data collection subjects rest laying supine for 20 minutes to allow their feet to reach a resting baseline state. At the end of rest, subjects remove their shoes and their plantar surface temperature is taken using an infrared thermal camera (FLIR T540sc, FLIR Systems, Wilsonville ,OR). Subjects then replace their shoes and walk for five minutes on a treadmill at a self-selected walking speed. At the completion of walking, the cooling behavior of the foot is examined with a series of time-lapse, thermal foot images acquired at 30 second intervals, for a duration of 20 minutes. Thermal data is processed in FLIR ResearchIR software by manually identifying biomechanically relevant regions of interest. The average temperature in each of these regions is recorded.

Biomechanical data are collected following the temperature data through overground walking. Kinematic data is captured using an 8-camera motion capture system at 180 Hz (Raptor 4S, Motion Analysis Corporation, Rohnert Park, CA), and force data is collected using an array of 8 in-ground force plates at 1080 Hz (AMTI Inc. Watertown, MA). Fourty-one retro-reflective markers, identifying pelvis, thigh, shank, and foot segments were placed on subjects for shod walking. Subjects walk at their self-selected speed until five successful trials are recorded for each foot (contact is contained entirely within a single force plate). The average work performed by each subjects' right and left feet are calculated using a unified deformable segment analysis [4]. Per-foot net, positive and negative work are compared to temperature increase during walking.

RESULTS AND DISCUSSION

Data collection is currently ongoing, and early results are presented for the first three healthy adults (six feet) who have completed our protocol and completed processing (**Fig. 1**). In this small early sample, no strong trends are seen between work and temperature change.

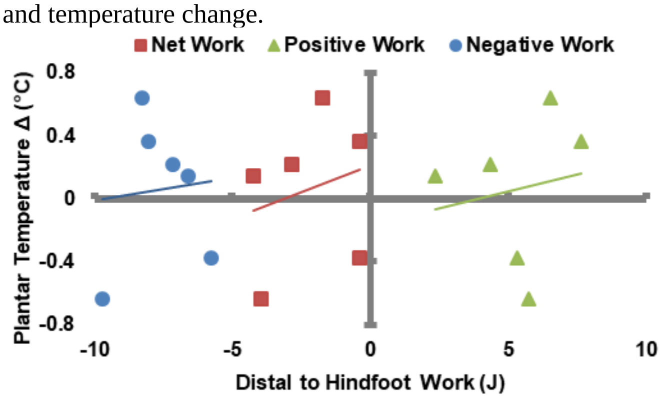

Figure 1: Net, positive and negative distal to hindfoot work vs plantar temperature change after 5 minutes of shod walking. Three healthy subjects (6 feet) have currently been processed.

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Influence of hip abductor fatigue on ACL loading during single-leg landing

Namwoong Kim[1] and Brian Knarr[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: namwoongkim@unomaha.edu
Presentation Preference: [(3) **Poster Only**]

INTRODUCTION

An estimated 100,000 anterior cruciate ligament (ACL) injuries occur each year in the United States[1]. Approximately 70% of the ACL injuries are caused from a non-contact mechanism (with no direct blow to the knee joint) during a landing or in cutting. According to recent studies, weakness of hip abductors may contribute to greater hip adduction or internal rotation during dynamic activities such as landing or jumping. These abnormal hip joint mechanics may lead to knee valgus collapse and it is considered to be the most common mechanism for ACL injury. Conversely, only a weak association was reported between hip abductor weakness or fatigue and knee joint mechanics. Previous studies were limited to hip or knee joint mechanics and no study is reported on hip abductor weakness and ACL loading during simulated athletic events such as single-leg landings.
To understand the cause and effect relationship between hip abductor weakness and ACL loading during single-leg landing, we need an experimental study. However, an internal force such as ACL loading cannot be easily studied in vivo during movements. Computer models of the musculoskeletal system offer a promising means to estimate ACL loading.
The purpose of this study was to identify the effects of hip abductor fatigue on ACL loading during single-leg landing. We hypothesized that induced hip abductor weakness will result in greater ACL loading during single-leg landing.

METHODS

Human experiment
10 healthy adults participated in this study (5 females, age 26.6 ± 1.35 years; height 1.75 ± 0.7 m, mass = 71.1 ± 14.1 kg). Three dimensional marker position data were collected at 200Hz by using a 3D motion capture system while the participants were performing single-leg landings from a height of 45 cm onto a force platform. Each participant performed single-leg landings in pre and post hip abductor fatigue conditions until they succeed 3 trials of single-leg landings for each condition. Fatigue protocol included the 3 sets of side-lying hip abduction to induce hip abductor weakness. The participants were asked to perform side-lying hip abduction for as many repetitions as possible at a pace of 60 bpm provided by metronome until they were unable to reach the target set to a height that corresponded to 35° of hip abduction. To confirm hip abductor fatigue, median frequency of EMG activity of gluteus medius was calculated, and it has decreased by 33% (pre: 58.71, post: 39.21 Hz) after the fatigue protocol.
Musculoskeletal model
Ten 31 degree-of-freedom (DOF), 92 muscle-tendon actuated subject-specific models were developed in OpenSim[2-3]. Knee joint of the model has 5 DOF that include all three planes of rotation, sagittal and transverse plane translation. The model includes an ACL from previous study and it is scaled to each participant. ACL loading was calculated from initial contact (IC) to maximum knee flexion (MKF) using change in ACL length and the linear elastic stiffness which was 240 N/mm. The model generated a 3D, inverse dynamic simulation based on motion capture single-leg landings.

RESULTS AND DISCUSSION

No differences between conditions were found in peak ACL loading (pre: 884.15± 124.80, post: 896.40 ± 110.37), knee flexion (pre: 65.54 ± 7.68, post: 66.74 ± 7.21), knee abduction (pre: 5.81 ± 6.18, post: 5.87 ± 5.42), and knee internal rotation angle (pre: 8.98 ± 6.93, post: 8.15 ± 8.04). The mean peak ACL loading (12.52 N/kg) was well aligned with the previous study[3] in low-risk group (13.04 N/kg).

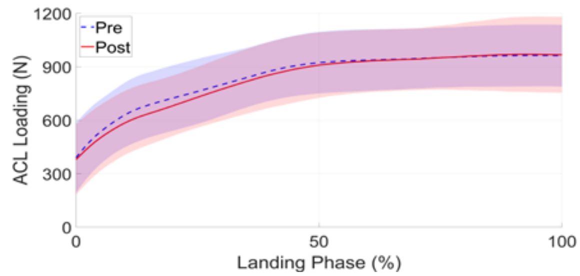

Figure 1: Mean and SD of time-normalized ACL loading during the single-leg landing trials before (blue dashed) and after (red solid) fatigue from IC to MKF.

Table 1: Peak ACL loading and Knee Kinematics before and after Fatigue

	Prefatigue	Postfatigue	
Variable	**Mean±SD**	**Mean±SD**	***P* Value**
ACL loading (N)	884.15± 124.8	896.40 ± 110.3	0.414
Knee Flexion	65.54 ± 7.68	66.74 ± 7.21	0.584
Knee Abduction	5.81 ± 6.18	5.87 ± 5.42	0.923
Knee IR	8.98 ± 6.93	8.15 ± 8.04	0.230

CONCLUSIONS

We only used successful trials maintaining balance without falling over or touching the ground with their non-dominant leg, which may mask the effect of hip abductor fatigue on ACL loading during single-leg landing. Comparing successful trials with unsuccessful trials may be necessary to identify the effect of hip abductor fatigue on ACL loading during single-leg landing. Future study will focus on determining what extent weakness of hip abductors start to alter ACL loading during single-leg landings, and what compensation occurred in other joints during single-leg landings after hip abductor fatigue.

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Single Session Walking Adaptations to an Ankle Foot Orthosis in Patients with Peripheral Artery Disease

Todd Leutzinger[1], Iraklis Pipinos[2, 3], Jason Johanning[2, 3], Mukul Mukherjee[1], Sara Myers[1, 2]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]Nebraska and Western Iowa Veterans Affairs' Medical Center, Omaha, NE USA
[3]Department of Surgery, University of Nebraska Medical Center, Omaha, NE USA
Email: tleutzinger@unomaha.edu

Presentation Preference: **Poster** or **Podium**

INTRODUCTION

Peripheral artery disease (PAD) is an atherosclerotic occlusive disease affecting the arteries of the legs (1). The primary symptom of PAD is intermittent claudication, classified as walking-induced ischemic leg pain. An ankle foot orthosis (AFO) is a carbon fiber device that is able to absorb and store mechanical energy during the single stance phase of gait and return it to the body during push-off. This absorbed and returned energy decreases the load on the plantarflexor muscles during walking through the substitution paradigm. Wearing an AFO has shown promise in improving maximal walking distance in patients with PAD (2), however, the length of time needed to adapt to the AFO is unknown. The purpose of the current study is to evaluate if a single walking session is sufficient for patients with PAD to adapt to a passive AFO.

METHODS

Kinematic and spatiotemporal walking data were collected using retro-reflective markers placed on the subject and AFOs at specific anatomical locations (3). Twelve patients with PAD performed a standardized progressive load treadmill test during which subjects walked on a treadmill at 2.0 mph starting at 0% grade (4). Every two minutes the treadmill grade increased by 2% up to a maximum of a 15% grade. Subjects performed the test for as long as they were able until claudication forced them to stop. Subjects performed the test twice in each data collection, once with the AFO and once without the AFO (NAF). The order of these conditions was randomized.

Walking data were analyzed at three levels of claudication pain: pain free (PF), initial claudication (IC), and absolute claudication causing the end of the trial (AC). Stance times during the AFO trials were subtracted from stance times during the NAF trials at each respective level of claudication pain. These differences were compared across levels of claudication pain to determine spatiotemporal adaptation. The same method was also performed using swing time data. Coefficient of determination (CoD) values were determined by correlating normalized joint angles at each level of claudication pain between the NAF and AFO conditions. Comparisons of CoD values across levels of claudication and with a value of 1 (NAF walking alone) were performed to test for kinematic adaptations. One-way analysis of variance (ANOVA) tests were used to determine adaptations with $p = 0.05$.

RESULTS AND DISCUSSION

There was no main effect of level of claudication pain in the stance and swing time differences between AFO and NAF walking. This may be because there were no significant differences in stance times or swing times between AFO and NAF walking at any level of claudication pain. There was no significant effect of level of claudication pain on CoD when walking with the AFO, but there were significant effects for joint angle patterns between AFO and NAF walking for all joints at all levels of claudication pain.

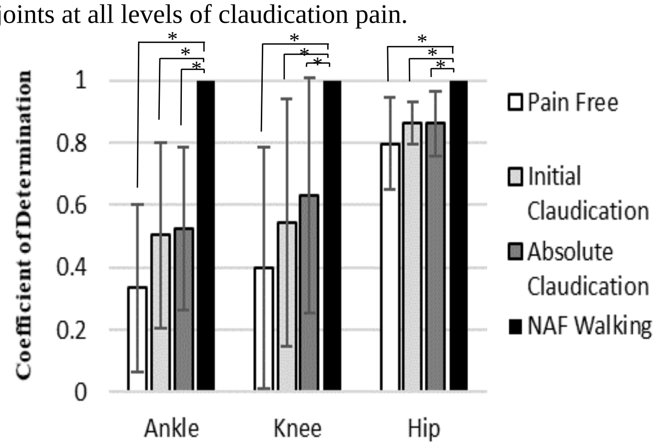

Figure 1. Coefficient of determination (CoD) values during three levels of claudication pain and walking without the AFO (NAF). Data were calculated by correlating lower limb joint angles of AFO and NAF walking trials. An asterisk (*) indicates significant differences.

CONCLUSIONS

Significant effects for CoD values between AFO and NAF walking indicate subjects produced significantly different joint angle patterns when walking with the AFO compared to NAF walking. This did not translate into changes in CoD values with prolonged claudication pain, indicating subjects did not adapt joint angle patterns throughout the single walking session. Future studies should investigate how individuals with PAD adapt to an AFO over multiple trials.

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Multifractal Correlation Reveals Variation in Complexity Matching across Metronome Types

Aaron D. Likens[1], Luis Silva[1], Douglas Rowen[1], João R. Vaz[1,3], & Nicholas Stergiou[1,2]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]College of Public Health, University of Nebraska Medical Center, Omaha, NE USA
[3]Universidade Europeia, Lisbon, Portugal

Presentation Preference: **Poster** or **Podium**

INTRODUCTION

Recent studies have explored the statistical properties that emerge when synching movements with noisy metronomes [1]. That work suggests that coordination entails many spatial and temporal scales. Complexity matching (CM) is revealed when similarity emerges between the time-based statistical properties (e.g., fractal, random) of coordinated components (e.g., limbs, people). Additional work is needed to understand the structural properties of metronomes that promote this form of coordination. This exploratory study makes use of the recently introduced multifractal correlation analysis [2] to investigate patterns of CM between stride intervals and visual metronome intervals with 3 general forms: periodic, fractal, and random.

METHODS

Eight adults (22.25±1.28 years) walked on a 200 m track while matching their steps to visual stimuli. Stimuli were vertically oscillating bars displayed on a video screen attached to glasses (Vufine®, USA). Bivariate series of stride and metronome intervals were analyzed with multifractal correlation analysis.

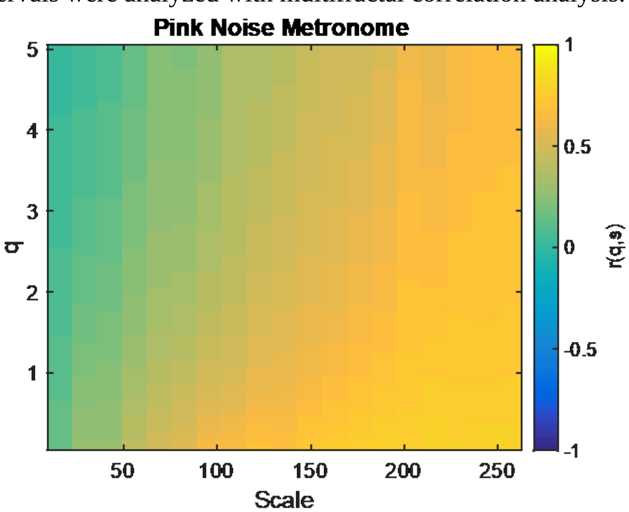

Figure 1: Ensemble average colormap depicting multifractal correlation for the fractal metronome condition for Scale ranging from 16 to 256 beats and q ranging from 0.1 to 5. Here q refers to q-order statistics common in multifractal analysis. r(q,s) is the q by Scale correlation coefficient that ranges from -1 to 1. For small q, small fluctuations dominate the computation; the opposite is true when q is large. Large positive r(q,s) appear at most scales and q values.

RESULTS AND DISCUSSION

We found that the fractal metronome generated the strongest overall correlation structure across broad ranges of Scale and q (Fig. 1-3). Moreover, the periodic metronome showed the weakest (near zero) multifractal correlations among the three conditions.

CONCLUSIONS

Synching with fractal metronomes entails multiple time scales

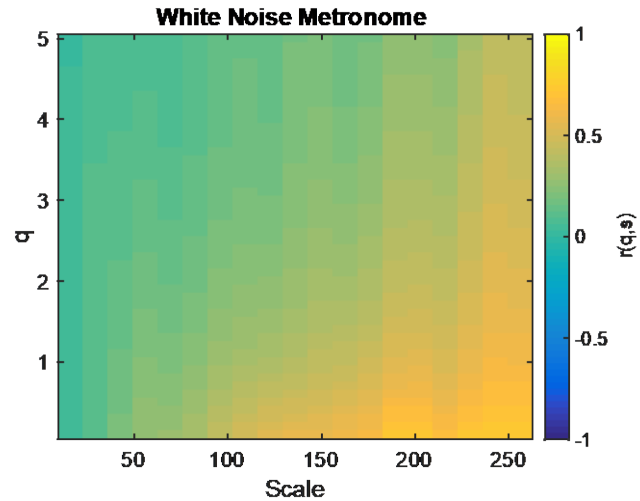

Figure 2: Ensemble average multifractal correlation for the random metronome condition. Strong correlations only emerge at the largest time scales.

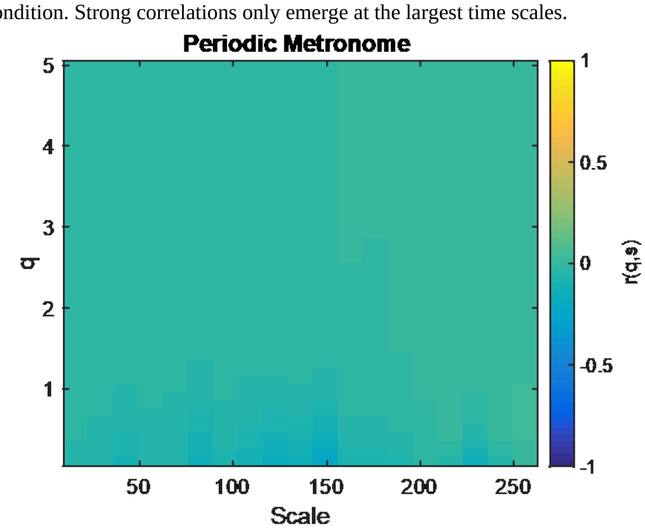

Figure 3: Ensemble average multifractal correlation for the periodic condition. Only weakly negative correlations emerge at intermediate scales.

and fluctuations of many sizes possibly indicating improved walking adaptability. In contrast, random signals mostly involve large scales and small q, perhaps reflecting statistical learning of the mean interval. Moreover, synching with a periodic signal involves only smaller time scales and fluctuations, implying a corrective form of synchronization.

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ACKNOWLEDGEMENTS
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THE EFFECTS OF A SHOCK-ABSORBING PYLON ON MECHANICAL WORK

Jenny Anne Maun[1], Steven A. Gard[2,3], Matthew J. Major[2,3] & Kota Z. Takahashi[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]Northwestern University Prosthetics-Orthotics Center, Northwestern University, Chicago, IL, USA
[3]Jesse Brown VA Medical Center, Chicago, IL, USA
email: jmaun@unomaha.edu

Presentation Preference: (3) **Poster Only**

INTRODUCTION

Shock-absorbing pylons (SAPs) are designed to reduce the impact of forces applied to the limb in prosthetic users [1,2]. Individuals with transtibial amputation (TTA) typically prefer SAPs because of its comfort and tendency to reduce residual limb pain [1]. Previous research suggests that SAPs can attenuate impact forces during gait [1]. However, it is currently unclear how SAPs and its components (e.g., spring stiffness) affect the mechanical work done by the prosthetic limb during gait. Therefore, the purpose of this study was to investigate the effects of spring stiffness of SAPs and walking speed on the mechanical work of the prosthetic limb in individuals with TTA throughout stance. We hypothesized that a more compliant spring will result in more negative work during early stance phase, and subsequently produce more positive work (i.e., greater energy stored and returned during the entire stance). We also hypothesized that an increase in walking speed will amplify the effects caused by different prosthetic stiffnesses on mechanical work due to a proportional increase in ground reaction forces.

METHODS

A secondary analysis was performed on sample data (5 out of the 12 subjects with TTA) from a previous study (1F/4M; age: 50.2±19.9yrs; height: 1.80±0.08m; weight: 91.0±19.6kg; time since amputation: 14.2±13.3yrs; means ± standard deviation) [2]. All subjects provided informed consent and the study was approved by the Northwestern University Institutional Review Board. More detailed information on the experimental prosthesis was described in the previous study [2]. Subjects wore their own socket and suspension system while wearing the experimental prosthesis. A Modified Helen Hayes marker set was applied with an additional marker placed on the distal end of the telescoping pylon. Subjects walked at two self-selected walking speeds: customary and fast. Four prosthetic stiffnesses (Table 1) were tested: soft (50% of normal), medium (75% of normal), normal (manufacturer-recommended), and rigid (no displacement). Kinematic and kinetic data were processed in Visual3D (C-Motion Inc., Germantown, MD, USA) using a lowpass, 4th-order Butterworth filter with cut-off frequencies at 6Hz and 25Hz, respectively. Ankle-foot power was calculated using the Unified Deformable (UD) power analysis method [3]. Statistical analysis was performed using a two-way repeated measures ANOVA to find main and interaction effects of stiffness and speed on the positive and negative work of the prosthetic limb ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Our first hypothesis was not supported as no significant difference was found in the negative work across all stiffnesses ($p=0.85$), even though the most compliant spring produced the most negative work (mean: -30.3±9.4J) and the stiffest spring produced the least negative work (mean: -22.8±7.9J). Similarly, positive work across all stiffnesses were also not statistically significant ($p=0.47$). Furthermore, our second hypothesis was not supported as there was also no significant interaction effect between stiffness and speed in negative work ($p=0.80$) and positive work ($p=0.83$). There was a significant difference in the negative work across all speeds ($p=0.04$) where fast walking produced larger negative work (mean: -34.6±12.8J) than self-selected walking (mean: -27.2±8.1J). However, positive work was not statistically significant ($p=0.47$). Despite containing helical springs to minimize damping, the SAP's damping components may still contribute to the overall lack of significance as its rubber gasket slides on the pylon during spring compression/extension [1].

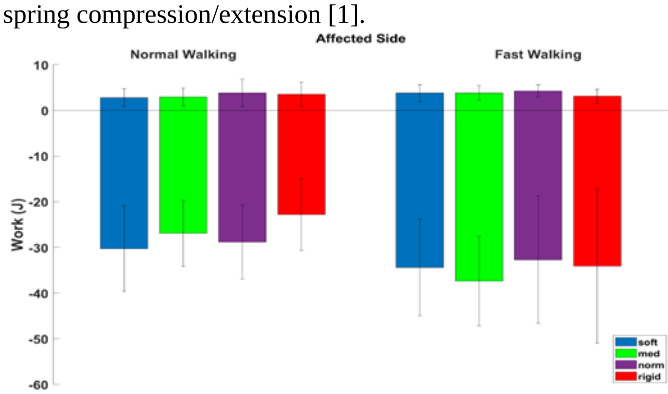

Figure 1: Average prosthetic ankle-foot work throughout stance.

CONCLUSIONS

From the preliminary results, softer springs produced more negative work at customary walking but this was not significantly different. Interestingly, positive work was similar across all stiffnesses and speeds, potentially indicating that not all of the SAP's energy is stored and returned for push-off. This energy lost during stance may be transferred to heat or to energy dissipation due to damping materials within the prothesis. Future research will analyze the additional subjects and investigate how the energy is transferred from the prosthesis to the user during gait.

ACKNOWLEDGEMENTS

Thank you to Rebecca Stine, MS, at the Jesse Brown VA Medical Center for conducting the data collections.

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Table 1: Average self-selected speeds (customary and fast) for each prosthetic stiffness condition.

Spring Sets 1/2 Prosthetic Stiffnesses (kN/m)	Soft (68.2/85.6)	Medium (89.3/111.8)	Normal (111.8/153.8)	Rigid (3556.9)
Self-Selected Customary Walking (m/s)	1.27±0.22	1.27±0.23	1.20±0.21	1.20±0.24
Self-Selected Fast Walking (m/s)	1.56±0.39	1.55±0.41	1.54±0.39	1.54±0.39

NEURAL MECHANISMS UNDERLYING SENSORIMOTOR SYNCHRONIZATION WITH DIFFERENT FORMS OF RHYTHMS

Ryan L. Meidinger[1] & Vivien Marmelat[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
Email: sc2d.labuno@gmail.com

Presentation Preference: **Poster** or **Podium**

INTRODUCTION

Neuronal activity, like behavior [1], synchronizes with periodic rhythms, reflecting beat perception [2]. Neural activity exhibits a form of non-periodic rhythm known as fractal fluctuation [3]. It is unknown whether neuronal activity synchronizes with non-periodic rhythms, but if it does, it is believed to be utilizing complexity matching to integrate information [3]. The purpose of the present research is to determine the neural mechanisms present while listening to and tapping with different auditory metronomes. Our central hypothesis is that the amplitude envelope (AE), interbeat intervals (IBIs), and intertap intervals (ITIs) will match to varying degrees. We believe that the fractal will be the most easily matched metronome because it presents biologically relevant stimulation.

METHODS

Twenty young healthy adults without hearing impairment nor musical training will be recruited to participate in the present study. Participants will be fitted with a 128-channel electroencephalogram net (EEG, EGI, Eugene, OR, USA, 1000 Hz) in the 10-20 system. Participants will be instructed to tap their dominant hand index finger with the metronomes in all tapping conditions. Each condition will last five minutes, separated by two minutes rests (see Figure 1). When participants are required to tap their dominant hand index finger, a pressure sensor (Delsys, Natick, MA, USA, 15 0Hz) will be used to record finger tapping data.

Inter-beat intervals (IBIs), inter-tap intervals (ITIs), and the amplitude envelope (AE) of EEG signal of all frequency bands of the temporal, frontal, and motor regions of the brain will be assessed with DFA. The result of DFA will be the alpha scaling exponent (α-DFA), informing about the structure of the variability of the time series. Event related potential (ERP) N1 will be analyzed in the frontocentral electrodes, to estimate the neural responses to each beat in a time window of roughly 100-200 milliseconds prior to beat onset. A two-way repeated measures analysis of variance ($p<0.05$) will be utilized to assess differences between conditions for timing of ERPs. A Pearson-r will be used to assess the relationship between the α-DFA of the IBI, ITI, and AEs. Coefficient of Variation will be used to assess the variability of ERP N1 to beat onset the within 100-200 millisecond window and tapping asynchrony.

RESULTS AND DISCUSSION

Data for the present research is currently in the process of being collected. The IBIs, ITIs, and AE are expected to significantly relate for α-DFA in all trials, as it has been shown that physical and neuronal activity match external stimuli [1]. It is also expected that this will appear across the brain regions studied, indicative of information integration [3]. The ERP N1s are expected to significantly vary to a larger degree in the random, compared to the fractal and isochronous conditions as the brain exhibits fractal fluctuations [3] and synchronizes with isochronous (periodic) rhythms [1].

CONCLUSIONS

This research will give insight into the ability of the brain to complexity match to not only recreate the rhythm of auditory signals within the brain but also with behavior. Brain activity may more readily match to fractal rhythms and isochronous rhythms because they are biologically relevant and predictable, respectively.

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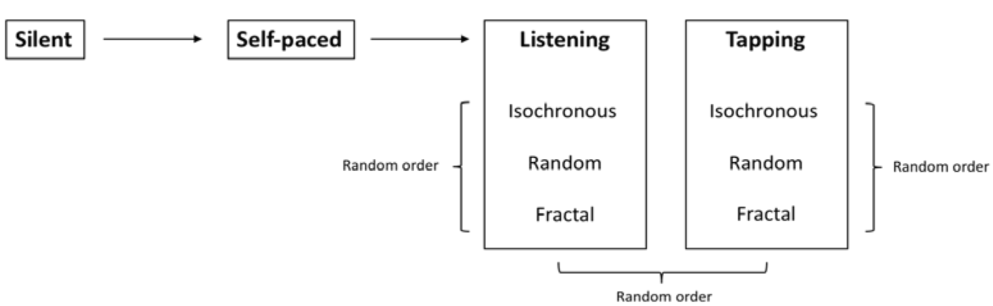

Figure 1: All participants will do the baseline listening and self-paced tapping in the order above and then will perform the trials as shown above: counterbalanced and randomized.

EFFECT OF DUAL-TASK WALKING ON LONG-RANGE CORRELATIONS IN PEOPLE WITH PARKINSON'S DISEASE

Shane Meltz[1], Danish Bhatti[2], John Bertoni[2], Vivien Marmelat[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE, USA
[2]Department of Neurological Science, University of Nebraska Medical Center, Omaha, NE, USA
email: sc2d.labuno@gmail.com

Presentation Preference: [(1) Poster or Podium]

INTRODUCTION

Parkinson's disease (PD) is a neurodegenerative disorder that impacts executive and motor functions [1]. Walking requires executive function and attention [2], but performing a secondary cognitive task while walking (i.e., dual-tasking) can impact the performance in one or both tasks. During steady-state walking, stride time series present persistent long-range correlations (LRC) over the span of hundreds of strides [3]. LRC create a fractal pattern meaning that fluctuations at one-time scale are statistically similar to fluctuations at a variety of other time scales [4]. LRC are useful as assessing the control of gait, and have been shown to identify pathological and age-related changes in gait dynamics [6-7]. However, the effects of dual-task walking on LRC are still unknown. The aims of this study are 1) to compare an attention-demanding task on gait variability in people with PD to age matched controls; and 2) to determine the relationship between fall history and gait variability during dual-task walking in people with PD. Our central hypotheses are that 1) during dual-task walking, people with PD will present a greater magnitude and more random ordering of LRC's compared to single-task walking and compared to age matched controls; and 2) the number of previous falls will be associated with a greater magnitude and more random ordering of LRC's during dual-task walking.

METHODS

Forty people with Parkinson's disease (age>60), and forty age and gender matched healthy elderly will participate in the study. Subjects with PD will have a Hoehn & Yahr disease severity between 1 and 3. All participants will complete a medical history along with questionnaires and clinical assessments testing cognitive ability, fear of falling, depression, balance, mobility, and freezing of gait (if applicable). All participants will be examined for the effects of dual-tasking by performing three separate conditions in random order. Condition one will test seated cognitive performance, which includes sitting in a quiet room and listening to an audiobook through headphones for 10 minutes. After which participants will answer 10 questions regarding the context of the audiobook and report the number of times two pre-defined words appeared. Condition two will be over ground walking at self-selected speed for 10 minutes. Condition three will consist in performing both tasks at the same time to test dual-tasking performance.

Long-range correlations will be assessed through the detrended fluctuation analysis (DFA). Cognitive performance will be assessed through performance on the word monitoring tasks and context questions. Two-way ANOVA's will be used to compare the outcomes between normal and dual task walking. Spearman correlations will be used to correlate the number of falls to the DFA value from single and dual task walking.

RESULTS AND DISCUSSION

The IRB was approved in January 2019, so we expect to have collected at least 20 participants in each group by the time of the conference. Our hypothesis is that people with PD will present a greater magnitude and more random ordering of stride-to-stride fluctuations compared to age matched controls. In a pilot collection, DFA showed a decrement from single to dual-task walking in a healthy young adult (Figure 1). This shows that even healthy young are susceptible to dual-tasking decrements in LRC. We also predict that a previous self-reported fall history will correlate to a larger decrement in LRC's during dual-tasking, because a decrement in LRC has been linked to disease severity [7]. However, since people with PD already experience walking impairments this may lead to less decrement, since people with PD possibly have less room to change.

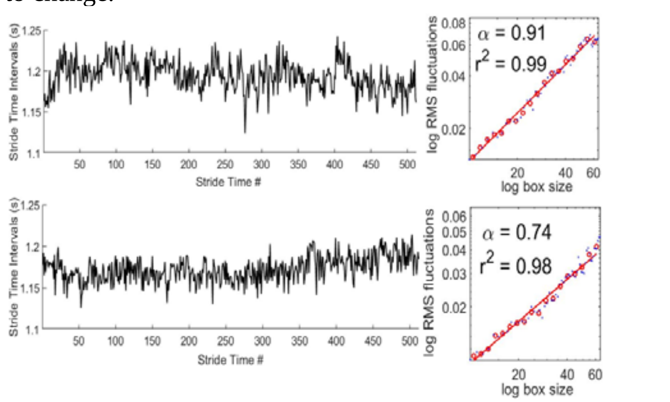

Figure 1: Reduction of DFA from single (top) to dual-task walking (bottom) in a young participant.

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INFLUENCE OF MUSIC AND METRONOME ON GAIT AND SELF-REPORTED PREFERENCES IN PEOPLE WITH PARKINSON'S DISEASE

Shane Meltz[1], Ryan Meidinger[1], Austin Duncan[1], Amy Hellman[2],Vivien Marmelat[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA.
[2]Department of Neurological Science, University of Nebraska Medical Center, Omaha, NE, USA.
email: sc2d.labuno@gmail.com
Presentation Preference: [(1) **Poster or Podium**]

INTRODUCTION

Humans spontaneously synchronize their movements to external rhythms [1]. Rhythmic entrainment can be used to guide gait in people with Parkinson's disease (PD), who are impaired in their ability to produce internal rhythms [2]. Traditional rhythmic auditory stimulus (RAS) with periodic signals are periodically structured, which do not account for the normal biological fluctuations of human movement. Human walking present rhythms that are fractal by nature [3]. Therefore, fractally structured beats could lead to a better entrainment. We used two novel auditory stimuli 1) Fractal On-Step (FOS) which was fractally structured with cues for each step; 2) Fractal On & Between Step (FOBS) which was fractally structured with cues for each steps and between-steps (Figure 1).

METHODS

We recruited 15 people with Parkinson's disease (PD Group; age 67.9 ± 9.2 years old), and 15 age-matched elderly adults (HE group; age 69.5 ± 11.2 years old). All participants were required to be able to walk independently and unassisted for 15 minutes continuously at their own preferred walking speed. All participants completed a medical history, and a battery of questionnaires and clinical assessments. After the initial assessment all participants walked around a 200m indoor track with Noraxon footswitches inserted in their shoes to record stride times. Participants walked under 3 conditions for 15 minutes each: first baseline without auditory stimuli, then FOS walking and FOBS walking in a randomized order. FOS walking consisted of a fractally structured metronome-like auditory stimulus, and was set to each participant's baseline cadence. Participants were instructed to match their steps with each beat. FOBS walking consisted of a fractally structured Fur Elise melody, where participants were instructed to match their steps with every other beat. The fractally structured beats were set to fluctuate by two percent around each participant's preferred walking speed. Between trials participants were given five to ten minutes of rest to account for fatigue. After the walking trials, participants filled out a questionnaire to assess self-reported difficulty and enjoyment in synchronizing to the stimuli. DFA and the coefficient of variations were applied to stride intervals, and two-way ANOVAs (groups x conditions) were conducted for each outcome.

RESULTS AND DISCUSSION

There were no significant differences between the HE group and PD group for any of the variables measured. DFA was significantly higher in the FOS condition compared to baseline (t (27) =2.309, p=0.029). The coefficient of variation significantly increased from baseline to FOS (t (27) = -2.096, p = 0.046) and music (t (29) = -2.443, p = 0.021).

There were significant effects between experimental conditions and self-reported enjoyment (F (1,1) = 12.336, p = 0.002), and difficulty (F (1,1) = 22.661, p < 0.001). Self-reported enjoyment was significantly higher in the FOS condition, as compared to FOBS, and difficulty was significantly higher in the FOBS condition, as compared to the FOS condition, suggesting that participants found the less difficult condition more enjoyable.

Table 1: Results comparing the three different conditions for both Parkinson's Disease group (PD), and Healthy Elderly group (HE).

		DFA n/8	CV	Mean	Enjoyment	Difficulty
		Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
PD	Baseline	0.76 ± 0.10	1.88 ± 0.69	1.07± 0.8		
	FOS	0.89 ± 0.06	2.34 ± 1.16	1.08 ± 0.10	76 ± 37	41 ± 38
	FOBS	0.84 ± 0.17	2.82 ± 0.16	1.10 ± 0.14	72 ± 37	65 ± 30
HE	Baseline	0.85 ± 0.13	1.86 ± 0.72	1.08 ± 0.13		
	FOS	0.89 ± 0.19	2.18 ± 0.85	0.99 ± 0.31	88 ± 27	28 ± 29
	FOBS	0.81 ± 0.16	2.41 ± 0.15	1.07 ± 0.13	79 ± 32	53 ± 36

CONCLUSIONS

FOS (i.e., metronome-like auditory stimulation) seems more beneficial to improve fractal dynamics in people with PD. Self-reported enjoyment also favors the FOS Stimulus, probably because FOS presented a stronger 'beat'. Future studies should evaluate the efficacy of a FOS-based training program to improve gait stability and gait adaptability in people with PD.

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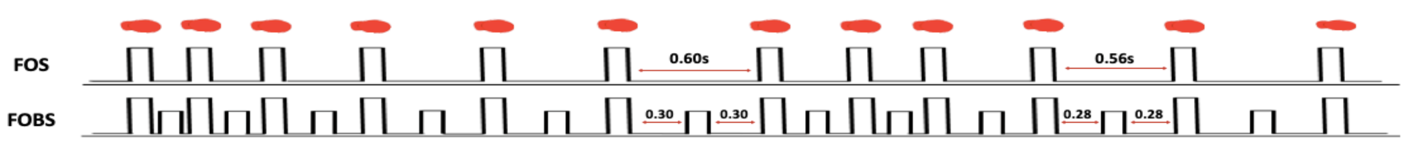

Figure 1: Graphical representation of the FOS and FOBS stimuli. Note that the between-beats in the FOBS stimuli are evenly spaced between the main beats.

HEALTHY YOUNG CAN FLEXIBLY SWITCH POSTURAL SWAY WITH DIFFERENT STIMULI

Zachary Motz[1], Takashi Sado[1], William Denton[1], & Mukul Mukherjee[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: zmotz@unomaha.edu, web: unomaha.edu/college-of-education/biomechanics
Presentation Preference: [(3) **Poster Only**]

INTRODUCTION

Space travel poses strong challenges to postural control. During space travel postural control undergoes sensorimotor recalibrations, and alleviating these changes is poorly understood.[1-3] Postural sway is affected by environmental changes, adapting to these changes and using gravitational cues allow us to maintain our upright stance. The ability to couple with different visual cues could serve as an exclusionary analog to spaceflight. If this expectation is accurate, then a rehabilitative task could serve to promote faster recovery and readaptation to the new environment. Thus, the goal of this study was to test the ability of flexibly switching postural entrainment from one stimulus to another.

METHODS

Fourteen young adults voluntarily shifted medial-laterally and attempted to match their own center-of-mass (COM) sway to a moving visual stimulus presented on a 180° virtual reality screen. The participants' displayed COM moved as they shifted their COM left- and right (Figure 1). Table 1 shows the conditions that were presented to the participant which included a periodic (sine wave), random (surrogated Lorenz) or chaotic (Lorenz) signals appearing in separate or combination trials.

The degree of COM – target coupling was quantified using cross-recurrence quantification analysis (cRQA), which represents the duration of coordination and cross-sample entropy (cSE), which represents the repeatability between the two signals. *Mixed factor ANOVAs were performed to determine coordination patterns for type of signal and effect of learning.*

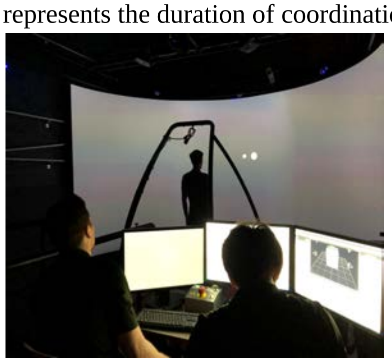

Figure 1: Image of apparatus set-up. Consisting of CAREN and 5-retroreflective markers.

RESULTS

For cSE, the there was a main effect of baseline signal type (conditions 2-4) with all signals different from each other ($p<0.01$). For mean diagonal line length in cRQA, participants tracked the periodic stimulus significantly different than the chaotic and random stimuli ($p<0.001$) however, the chaotic and random stimuli did not differ. There was also a learning effect seen during the combination trials (5-7), in that participants tracked the chaotic and random stimuli better at the end of the trial then at the beginning (cSE $p<0.001$; cRQA mean diagonal line length $p<0.001$)

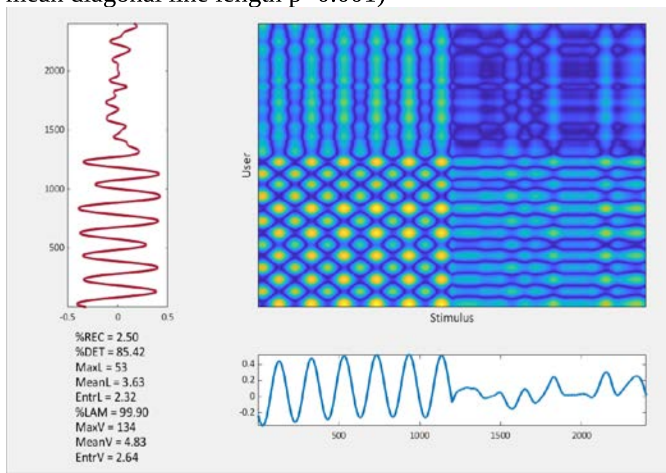

Figure 2: cRQA heat map of transition zone in condition 5. Stimulus is along the bottom and switches from a periodic to random stimulus, while the user's COM is along the Y-axis.

DISCUSSION & CONCLUSIONS

Across baseline and combined signals, the predictable (sine) stimulus showed increased repeatability and coupling duration across trials; and as a group had higher repeatability and coupling duration than the Lorenz and random stimuli. Switching between predictable and unpredictable or deterministic and unpredictable stimuli may use different strategies and depend on the direction of transition. Future studies should test different populations to determine adaptive flexibility across ages and pathologies. Transitions should be further explored to determine uncoupling-coupling characteristics.

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		Randomized			Randomized			Randomized			
Condition	1	2	3	4	5	6	7	8	9	10	11
Signal	Static	Sine	Lorenz	Random	Sine+ Random	Lorenz+ Random	Sine+ Lorenz+ Random	Sine	Lorenz	Random	Static
Time (s)	60	120	120	120	180	180	240	120	120	120	60

Stability Measures to Compare Fallers and Non-Fallers During Locomotion

Abderrahman Ouattas[1], Sheridan Parker[1], Jong-Hoon Youn[2], Brian A. Knarr[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]College of Information Science & Technology, UNO, Omaha, NE, USA
email: aouattas@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: [**Poster**]

INTRODUCTION

Falls represent a critical health issue for the elderly community as it causes injury, disability, and even death. Thus, maintaining postural stability during locomotion is essential to perform activity of daily living safely and efficiently. Maintaining stability during outdoor locomotion is as important to investigate as indoor environments. Wearable sensors are an effective tool to transform gait analysis in living environment. Previous studies have investigated the use of accelerometers to measure both static and dynamic balance between fallers and non-fallers indoors, which showed significant predictability with clinical balance tests[1] and motion capture (only on static balance)[2], in addition of being affective in identifying fallers from non-fallers during multi-task Timed-up-and-go.[3]

Variability measures have been used to assess stability in different environments only for young healthy[4], or between fallers and non-fallers during static balance but not during locomotion[5]. Despite the promising literature, limited research has investigated the effects of stability measures on identifying fallers safely within different environments. Therefore, the purpose of this study was to assess the sensitivity of outside motion measures relative to the in-lab motion measures using different stability assessments in elderly with history of falls.

METHODS

Four participants with a history of falling and six age-matched community dwelling participants were recruited (Table 1). Participants performed a 6-minute treadmill walk test indoors, and a 3-minute walk test on paved surface outdoors during self-selected (SS) speed. Participants were asked to not use the handrails during indoor trials unless necessary. A split-belt treadmill (Bertec) and motion capture system (16 camera Vicon) were used to collect biomechanical data indoors. An IMU-based system (Xsens,) was used to collect biomechanical data indoors and outdoors. Xsens and Vicon were synchronized during indoor trials. Maximum voluntary isometric contraction was used to determine stronger and weaker limb (Biodex).

Two methods were used to assess stability. A/P and M/L Margin of Stability (MOS)[6] at heel strike for each limb were used to analyze motion capture data. Means and minimums were included. Lyapunov exponents (LyE)[7] of M/L pelvis sway and pelvis acceleration, for motion capture and accelerometer data respectively, were used as a measure of gait stability. Independent t-test was used to measure the difference in stability measures between fallers and non-fallers groups. Regression analysis were used to measure correlation between LyE pelvis sway (Mocap) and pelvis acceleration (Xsens).

RESULTS AND DISCUSSION

LyE showed significant differences in ML pelvis sway ($p<0.05$) (Figure 1) but did not show any significance in ML pelvis acceleration during indoor treadmill trials ($p=0.84$). Moreover, LyE ML pelvis acceleration did not show significant differences during outdoor paved trials ($p=0.41$).

No significant differences were seen between fallers and non-fallers in AP and ML MOS at HS of both stronger and weaker limbs. Only minimum ML MOS of weaker limb almost reached significance ($p=0.0505$). No correlations were seen between LyE pelvis sway and LyE pelvis acceleration in fallers and non-fallers.

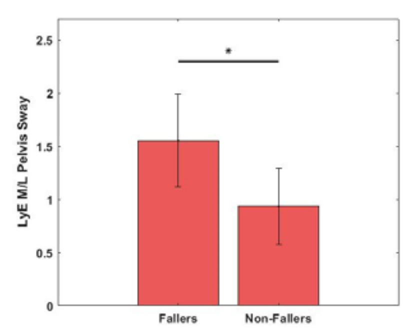

Figure 1: LyE M/L Pelvis Sway Differences Between Fallers & Non-Fallers

CONCLUSIONS

Our main finding indicates LyE of ML pelvis sway using motion capture may be the best method to indicate elderly with a history of falls during indoor self-selected gait, which could be due to its ability to measure variability of pelvis sway on a wider scale using a more precise measure of motion. From our initial findings, accelerometer data was unable to differentiate between fallers and non-fallers during both indoor and outdoor trials.

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Table 1: Participant Demographic

Participants	Last Fall (months)	Age (years)	Height (m)	Weight (kg)	BMI (kg/m^2)	SS Speed (m/s)	Gender
Fallers (4)	9 ± 6	67 ± 6	1.65 ± 0.06	68.34 ± 16.92	24.68 ± 5.33	0.91 ± 0.26	3 F 1M
Non-Fallers (6)	-	67 ± 3	1.73 ± 0.12	83.07 ± 16.17	27.52 ± 3.48	1.06 ± 0.09	4 F 2M

EFFECT OF AGE AND PARKINSON'S ON MULTISCALE ENTROPY OF ELECTROMYOGRAPHIC SIGNALS FROM LEG MUSCLES DURING OVER GROUND WALKING

Annette Pantall[1] & Arisara Amrapala[2]
[1]Clinical Ageing Research Unit, Institute of Neuroscience, Newcastle University, Newcastle, UK
[2]Royal National Orthopaedic Hospital, University College, London, UK
email: annette.pantall@newcastle.ac.uk

Presentation Preference: (2) **Podium Only**

INTRODUCTION

Falls are one of the leading causes of accidental death by injury in older adults (OA) and in age-related neurodegenerative diseases such as Parkinson's disease (PD). Dual-task walking (DTW) presents an additional falls risk. Greater understanding of motor control of gait is essential for developing effective therapies for reducing falls. Studies have shown that neuronal firing activity and electromyography (EMG) time series are not linear. Few studies have performed non-linear analyses on EMG in OA and people with PD. The purpose of this study was to investigate motor control through analysis of complexity of surface EMG signals. Complexity of EMG may indicate the richness of interactions within neural systems. The aims were to identify the effect of ageing and PD on complexity and how complexity is affected by walking tasks. Gender, muscle and symmetry were also examined. Based on the loss of complexity hypothesis and findings of current studies, it was hypothesized that people with PD have less complexity than healthy young adults (YA) and OA, and this complexity would further decrease during DTW due to cognitive-motor interference. Conversely, complexity was anticipated to increase during audio-cued walking (ACW) which decreases gait variability.

METHODS

A subsample of 15 individuals from a larger study group were randomly selected: 5 healthy YA, 5 healthy OA and 5 people with PD. Surface electrodes recorded EMG bilaterally from lower leg muscles using a wireless EMG system (Cometa Wave, Milan, Italy) sampling at 1000 Hz. This study reports on tibialis anterior (TA) and soleus (SO). Data were recorded under three conditions: normal walking (NW), DTW and ACW. A 30 second block of EMG was analyzed for each muscle for each walking task. All processing was performed in MATLAB 2018a. Surrogate analysis tested nonlinearity of EMG time-series. Optimal parameter calculation was undertaken yielding m = 2 and r = 0.25 [1]. Multi scale entropy was determined and complexity index (CI) calculated across scales 4 to 40 (25-250 Hz) [2]. Statistical significance testing was carried out using the Kruskal-Wallis test.

RESULTS AND DISCUSSION

People with PD had a lower CI across muscles compared to OA, although greater than YA (Table 1). No task effect was observed. Females had a significantly higher CI compared to males. The CI was greater in the left side compared to the right side (Table 1, Figure 1).

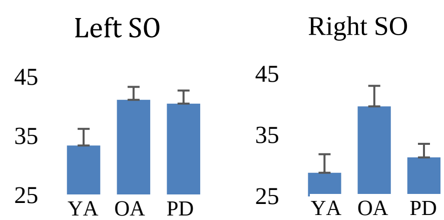

Figure 1: Complexity Index for EMG of soleus (SO) for YA, OA and people with PD.

The lower CI in PD compared to age matched controls supports our hypothesis. However, ageing was associated with greater CI. Older adults recruiting additional motor areas resulting in more complex neuronal motor control [3] may explain this. The simplicity of the cognitive memory task in DT may account for CI similarity between conditions. The asymmetry may be linked to limb dominance or the clockwise walking track. The greater complexity in females is intriguing and needs further investigation.

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Table 1: Kruskal-Wallis test for statistical significance between specific factors and complexity index (CI)

Factor	**Mean Complexity Index ± standard deviation**			***p-value***
Participant Group	79.6 ± 10.1 (**YA**)	102.3 ± 11.6 (**OA**)	89.6 ± 10.9 (**PD**)	0.058**
Walking Task	87.9 ± 11.1 (**NW**)	91.6 ± 11.4 (**DT**)	92.1 ± 10.7 (**AC**)	0.891
Muscle	86.3 ± 10.7 (**TA**)	95.0 ± 11.3 (**SO**)		0.242
Muscle Side	97.2 ± 9.9 (**L**)	83.8 ± 12.1 (**R**)		0.085**
Gender	66.7 ± 8.4 (**M**)	127.2 ± 8.4 (**F**)		<0.001

Changes over 36 months in nonlinear metrics of free-living gait in Parkinson's disease

Annette Pantall[1], Lucy Coates[2], Lynn Rochester[1], Silvia Del Din[1] & Jian Shi[2]
[1] Institute of Neuroscience, Newcastle University, Newcastle upon Tyne, U.K [2]
School of Mathematics, Statistics and Physics, Newcastle University, Newcastle upon Tyne, U.K
email: annette.pantall@newcastle.ac.uk

Presentation Preference: (1) **Poster** or **Podium**

INTRODUCTION

Gait analysis is emerging in health analytics as a tool for disease monitoring and a marker of progression. Wearable technology such as accelerometers allows ambulatory activity to be measured over extended time periods in both controlled and free-living environments. These large free-living data sets generated are more representative of the person's walking patterns. Characterizing locomotor dynamics through nonlinear measures, may provide insight into mechanisms of gait deterioration in neurodegenerative disorders such as Parkinson's disease (PD). Sample entropy is a nonlinear method that measures predictability of a signal. This study aimed to assess feasibility of evaluating metrics derived from sample entropy and the utility of these metrics in discriminating between PD and healthy older adults (OA) and longitudinal changes using accelerometry 7-day data.

METHODS

Free-living data over a 7-day period were recorded from OA and patients with PD as part of the Incidence of Cognitive Impairment in Cohorts with Longitudinal Evaluation - GAIT (ICICLE-GAIT) study [1]. We analyzed data from a subsample of five patients with PD and five healthy OA collected at 36-, 54- and 72-months post recruitment. A tri-axial accelerometer (Axivity AX3, York, UK) on the low back monitored movement and gait metrics were extracted [2]. Nonlinear features of stride time were determined. All processing was performed in MATLAB 2018a. Surrogate analysis tested nonlinearity of EMG time-series. Optimal parameter calculation was undertaken yielding vector m = 4 and threshold r = 0.25 [3]. Sample entropy was determined for stride times recorded over 7 days for OA and PD at 36, 54 and 72 months [4].

RESULTS AND DISCUSSION

Sample entropy was higher for stride time in people with PD compared to OA (Table 1). Over a period of 36 months sample entropy increased in the PD group from 0.61±0.05 to 0.79±0.27. The participants with PD showed greater divergence of sample entropy over 36 months compared to the OA group (Figure 1).

Table1: Sample entropy (SampEn) for surrogate stride data and original stride date for PD and OA groups at 54 months.

Group	Surrogate SampEn	Stride SampEn
PD	1.31±0.06	0.65±0.09
OA	1.27±0.09	0.55±0.11

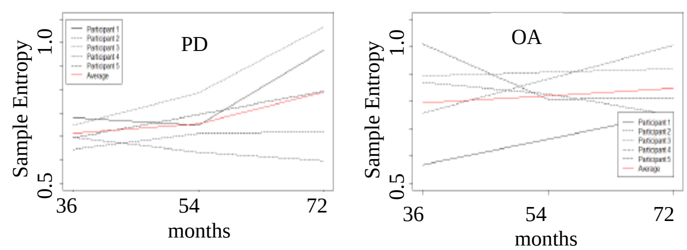

Figure 1: Individual trajectories of sample entropy over 36 months.

The greater sample entropy of stride time in PD may reflect the diminished automaticity of movement control in PD resulting in lower predictability or regularity of stride time. Increased divergence of sample entropy over a period of 36 months in PD may be the result of differing rates of disease progression.

CONCLUSION

Sample entropy can be applied to free-living data to extract information reflecting clinical status and progression. Nonlinear analysis has not previously been applied to longitudinal free-living gait data in PD. This novel study explores the feasibility and demonstrates the potential of nonlinear metrics to discriminate PD.

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Multiple Gearing Mechanisms of the Human Ankle-foot System during Locomotion.

Nikolaos Papachatzis[1], Samuel F. Ray[1] & Kota Z. Takahashi[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: npapachatzis @unomaha.edu, web:

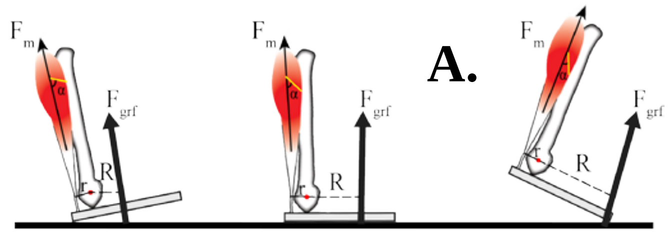
Presentation Preference: [**Poster Only**]

INTRODUCTION

The human musculoskeletal system contains numerous structures that perform analogous operations to levers or gears [1, 2]. The bones, joints and skeletal muscles make up the structure of a lever system, which act as gears by altering the leverage about the joint. Gears can improve movement efficiency, by maintaining the skeletal muscles at their optimal force-length and force-velocity relationship.

During locomotion, the human ankle-foot system can utilize various gear-like mechanisms that are present at different scales: such as a 'structural gear' at the joint/segment level [1], and a 'muscle gear' within the plantarflexor muscle fascicle level [2]. The structural gear mechanism, describes the dynamic changes of the ratio between the ground force moment arm (R) and the ankle plantar flexor muscles force moment arm (r) (R ⁄ r) [1]. During walking, the human foot behaves like a lever and the ankle joint as a fulcrum with two lever arms (r,R). This gear mechanism optimize the mechanical performance of the muscles. For example, during the push-off phase improves the muscle efficiency by maintain their optimal force-velocity relationships. The muscle gear mechanism, describes the ratio between the muscle velocity and fiber velocity (V_F/V_M). These two velocities are not necessarily equal. Due to the geometrical configuration, the velocity of the fiber (V_F) is not the only factor that determines the shortening velocity of the muscle (V_M). The muscle gear mechanism is highly variable and favor muscle speed during fast contractions and muscle force during slow contractions [Figure 1].

It is currently unclear whether the two seemingly independent gearing mechanisms (structural and muscle gear ratio) are functionally connected in any way. This information could help us to understand how the ankle-foot system takes advantage of the gear mechanisms in order to reduce metabolic cost [3]. In this study, we aimed to investigate the relationship of the two gear ratios by systematically altering the functions of the structural gear ratio via shoes and insoles [3]. We hypothesized that the structural- and the muscle- gear ratios will be positive correlated.



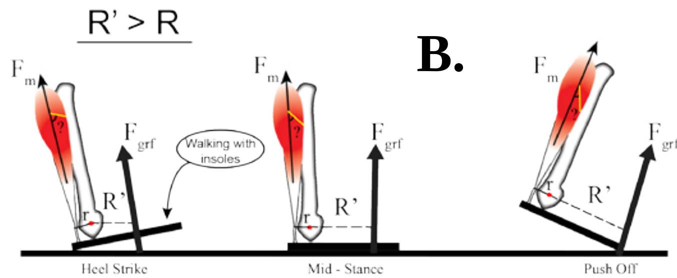


Figure 1: The muscle and structural gear ratios at the ankle foot system. The structural gear ratio is calculated as R ⁄ r. By measuring the fiber length (yellow line) and pennation angle (α) we calculated the muscle gear ratio as (V_F/V_M). Insoles (B) will increased R and allowed us to investigate the how changes in structural gear ratio affects the muscle gear ratio.

METHODS

12 males and 3 females aged 19 to 35 (mass 76.4±12.4 kg, height 176±7 cm) walked on an instrumented treadmill (Bertec, Columbus, OH) at three different foot stiffness conditions: (1) shoes only (7.2±1.3 N/mm), (2) shoes with 1.6mm carbon fiber insoles (32.4±8.7 N/mm), and (3) shoes with 3.2mm insoles (85.2±25.9 N/mm). An ultrasound probe (Telemed, UK) was placed on the right leg captured in-vivo soleus muscle contractions over time (sampled at 80 Hz). We quantified fascicle length and pennation angle changes, by using a previously validated automatic tracking software [4, 5]. The muscle velocity (VM) was calculated as the time derivative of the fascicle length projected onto the central axis. The muscle fiber velocity (VF) was calculated as the time derivative of the fascicle length [6]. For each stance phase, the muscle gear ratio was calculated as (V_F/V_M) and the structural gear ratio as the ratio of the lever arm of the ground reaction force and the moment arm of the plantar flexor muscle-tendon unit (R/r) [Figure 1]. The plantar flexor moment arm was measured as the distance between the lateral malleolus and the posterior aspect of the Achilles tendon. the relationship between the structural and muscle gear ratios was examined using a Pearson's correlation.

RESULTS AND DISCUSSION

We are currently analyzing the data that we have collected.

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Reliability of IMU System Compared to Motion Capture

Sheridan Parker[1], Abderrahman Ouattas[1], Brian A Knarr[1]
[1]Department of Biomechanics, University of Nebraska Omaha, Omaha, Nebraska, USA
Email: sheridanparker@unomaha.edu
Presentation Preference: (1) Podium or Poster

INTRODUCTION

Reliability between systems is necessary when used in conjunction to analyse human movement in different environments, such as laboratory and outside environments Previous literature has focused on the reliability of IMU systems compared to motion capture systems specifically in relation to a healthy population and traditional biomechanics measures such as peak joint angles [1,2]. It is unknown, however, whether motion capture and IMU systems are reliable for different populations such as an older adult or faller population. There is also a need to determine the reliability of these two systems using nonlinear analysis such as the Lyapunov exponent (LyE) which determines the variability in the evolution of the data, as oppose to linear measures of analysis that report values such as the peaks and means. Therefore, the aim of this study is to determine the reliability of an IMU system compared with a motion capture system using the Lyapunov exponent. We hypothesize that there will be no differences and a strong correlation between the motion capture and IMU condition in ankle, knee, and hip joint angle variability.

METHODS

Ten subjects participated in the study (67.9±5 years, 1.69±0.12m, 75.1±18.3kg, 3 males, 6 non-fallers, 4 fallers). Fallers were determined by the subjects' self-reported history of experiencing a fall within the past year. Informed consent was obtained before collection and the study was approved by the University Of Nebraska Medical Center IRB.

A 45-marker motion capture set was used concurrently with Xsens IMUs placed at the pelvis, and bilaterally at the thigh, knee, and foot. The Xsens system was synchronised with a Vicon motion capture system to record simultaneously. Subjects were asked to walk on the instrumented treadmill for 3 minutes at their self-selected walking speed while the motion capture and Xsens systems recorded simultaneously.

The LyE was calculated bilaterally for the ankle, knee, and hip joint angles for each system, motion capture and Xsens. Paired T-tests were performed on each joint angle comparing the LyE calculated from the motion capture system and Xsens system to determine the differences between the two systems. Pearson's r correlation was also calculated between the motion capture and Xsens systems to determine the similarity of the two systems. Significance was set to $p<0.05$.

RESULTS AND DISCUSSION

There are no differences in either motion capture or IMU systems for knee, or hip joint angle variability or between fallers and non-fallers ($p=0.17$) (Table 1). There is a positive correlation between the Vicon motion capture and Xsens IMU systems for the knee and hip joint angle variability (Figure 1). The motion capture and IMU systems are significantly different for the ankle joint angle variability while also not correlated.

Table 1: Paired T-test results comparing motion capture and IMU.

Joint	Xsens IMU LyE	Motion Capture LyE	Effect Size	p-value
Ankle	7.6 ± 4.5	5.5 ± 3.9	0.19	0.031**
Knee	1.9 ± 0.8	1.8 ± 0.8	0.022	0.26
Hip	1.9 ± 0.8	1.7 ± 1.3	0.022	0.26

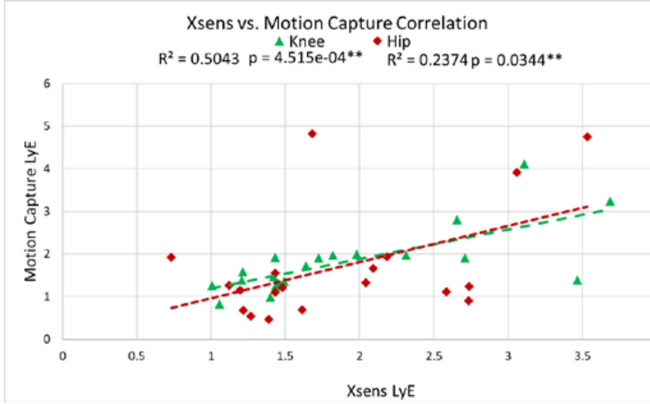

Figure 1: Correlation results comparing motion capture to the IMU system for the knee (green) and hip (red).

Previous literature has found minimal differences between motion capture and IMU systems with respect to joint angles and joint angular velocities [1,2]. However, the difference between the two systems seen in the ankle joint LyE may be attributed to a difference in system processing, a difference in the defined ankle joint center, or due to the ankle exhibiting a more complex motion. The subject population could also be an attributing factor to the wide range in ankle joint LyE, as fallers exhibit more variability in their gait kinematics [3]. A limitation of this study includes a small sample size.

CONCLUSIONS

While motion capture is the gold standard for research, the IMU system has the benefit of portability for use in outside environments. The interchangeability of using either of the two systems depends on the specific application. For knee or hip joint LyE, the two systems are reliable but not reliable for ankle joint LyE.

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USING SLOPED WALKING TO INVESTIGATE STRUCTURE-FUNCTION RELATIONSHIPS IN THE FOOT

Jeffrey M. Patterson[1] & Kota Z. Takahashi[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
Email: jmpatterson@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/
Presentation Preference: (1) **Poster** or **Podium**

INTRODUCTION

Walking on slopes is a prevalent form of human locomotion that necessitates adapting one's gait when compared to walking on level ground. Uphill walking requires greater production of positive mechanical work (i.e., energy generation) to raise the body's center-of-mass, whereas downhill walking requires greater negative work (i.e., dissipated energy) to lower the center-of-mass [1]. Previous studies have investigated how humans accomplish walking up or down slopes by examining the hip, knee, and ankle joints [2]. However, the foot's role in adapting to the varying energetic demands during sloped walking is currently unclear.

To generate greater amounts of positive work to walk uphill, the foot could be utilizing the windlass mechanism. This mechanism is an anatomical feature of the foot whereby dorsiflexion of the metatarsophalangeal (MTP) joints causes tightening and rising of the medial longitudinal arch in the foot [4]. The arch rises because of the connection of the plantar fascia (PF) between the calcaneus and proximal phalanges of the toes acting like a mechanical windlass. Dorsiflexion of the MTP joints is crucial to normal mechanical function of the foot [5]. Engaging the windlass mechanism more (i.e., greater toe dorsiflexion) during simulated gait increases energy storage in the arch through greater elongation of the arch [6].

Utilizing the windlass mechanism may aid incline walking, but the foot would need an alternative strategy for downhill walking. The heel pad is a large source of energy dissipation during normal level ground walking, capable of dissipating 17-19% of the total mechanical energy during the stance phase of gait [7]. Furthermore, the intrinsic muscles of the foot may be capable of behaving like brakes by acting eccentrically [3], further aiding in the energy dissipation required to walk downhill. Regardless of how the foot dissipates energy, it is of interest to see if the foot adapts to downhill walking by amplifying the amount of negative work it performs.

The purpose of this study is to investigate these structure-function relationships in the foot during sloped walking. It was hypothesized that walking on an inclined surface would increase positive work done by the foot, aided by the windlass mechanism through greater extension of the first MTP joint. Furthermore, it was hypothesized that downhill walking would increase the magnitude of negative foot work.

METHODS

We propose to collect data on 10 participants for this study. Subjects will be healthy, young adults aged 19 to 35 years old. All subjects will walk on a treadmill instrumented with force plates to collect kinetic data while simultaneous 3D motion capture cameras collect kinematic data. Subjects will walk for at least 1 minute at level ground (0° incline), at an incline (5° and 10°), and at a decline (-5° and -10°) at 1.25 m/s.

Multi-segment foot modelling in conjunction with inverse dynamics will yield lower extremity (i.e., hip, knee, ankle, and midtarsal) joint moments, powers, and work done, as well as midtarsal stiffness. The first MTP joint angle, midtarsal moment, foot power, and foot work will be compared between level and sloped walking conditions using an ANOVA.

RESULTS AND DISCUSSION

It is anticipated that when walking uphill, participants will utilize the windlass mechanism more because their toes will extend to greater angles. This should also help them to generate greater amounts of positive foot work necessary for inclined walking through greater midtarsal moment and foot power. Furthermore, during decline walking, it is anticipated that the foot will dissipate more energy (i.e., greater negative work). Although the analyses we propose to perform cannot ascertain if this negative work arises strictly from greater heel pad deformations or greater eccentric activity of intrinsic foot muscles, or both, it will serve as a starting point to understand the foot's role in sloped walking.

Although the current study is investigating healthy, young adults, it is our goal to understand what is occurring across the age span. Older adults are at a disadvantage in producing the necessary ankle joint torques required to maintain normal walking speeds on level ground, relying on proximal joints – namely the hip – to produce enough power and work [8]. Potentially, older adults may be at an even greater disadvantage in sloped walking if their feet and ankles are not able to adapt sufficiently to the task.

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BRAIN LATERALIZATION DIFFERENCES IN PEDIATRIC PROSTHESIS USERS

James Pierce[1], David Salazar[1], Keaton Young[1], Christopher Copeland[1], Claudia Cortes-Reyes[1], Walker Arce[1,2], Jorge Zuniga[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]Department of Electrical Engineering, University of Nebraska at Omaha, Omaha, NE USA
email: jepierce@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: **Poster** or **Podium**

INTRODUCTION

There are increasing numbers of children with traumatic and congenital amputations or reductions. The Centers for Disease Control and Prevention estimates that about 1,500 babies are born with upper limb reductions every year, and of these only 1 in 9,400 children is considered for prosthetic fitting.

Despite this increasing number of pediatric limb reductions, motor control and coordination in this population is still largely unexplored due to high cost and complex needs introduced by children's small size, constant growth, and psychosocial development [1, 2].

Advancements in computer-aided design (CAD) and additive manufacturing offer the possibility of designing and manufacturing prostheses at a very low cost [2]. By utilizing these technologies, exploration of underlying control mechanisms in novice amputees can be performed. Additionally, the creation of low-cost prosthesis simulators allows for an examination of typically developing control children and isolation of motor control factors introduced by prosthesis prescription itself.

The purpose of the present investigation was to determine the influence of upper-limb prostheses and prosthetic simulators on brain lateralization in the motor cortex compared to typically developing control children.

METHODS

Children with upper limb deficiencies (ULD) (n = 5) and typically developing, age- and sex- matched children (n = 5) performed reaching and gross motor tasks to assess function and brain activation.

Inclusion criteria included boys and girls from 3 to 17 years of age with unilateral upper-limb reductions. Exclusion criteria included upper extremity injury within the past month and any medical conditions that would be contraindicated with the use of our 3D printed prostheses prototypes.

The study was approved by the UNMC Institutional Review Board. All parents and children were informed about the study and parents signed a parental permission. For children 6 to 17, an assent was explained by the principal investigator and signed by the children and their parents.

All subjects performed functional tasks with their hands, and controls additionally used a prosthesis simulator on their non-preferred hand. The "Box and Block" test determined overall manual gross dexterity. [2] Functional Near Infrared Spectroscopy (fNIRS) was used to determine the laterality of brain activity during these functional tasks. [3]

RESULTS AND DISCUSSION

Laterality of brain activity during the performance of the Box and Block task appears to show heightened contralateral involvement in controls ($p = 0.296$), as expected. Alternatively, ULD subjects displayed less significance in their lateralization ($p = 0.626$) and had persistently higher left-hemisphere activation for tasks performed with both hands (Figure 1).

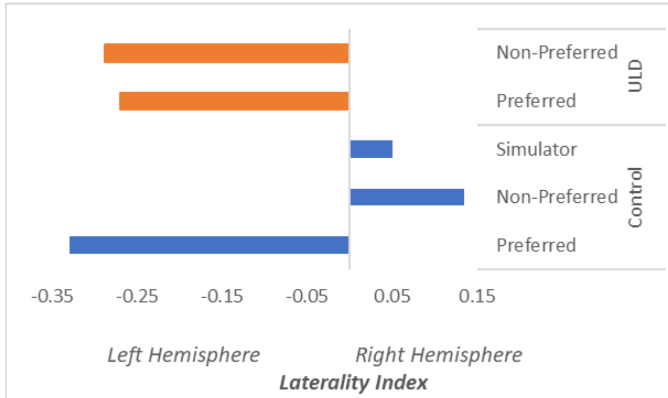

Figure 1: Laterality index (LI) during the performance of the Box and Block task for both groups and both hands.

CONCLUSIONS

It appears as though the laterality of brain activation may be affected in children with upper-limb deficiencies, resulting in lower specialization of neuronal networks and less efficient control during the course of the dexterity task. This could indicate the need for earlier prosthetic fitting, in order to facilitate more typical neurological development through childhood. Due to the small sample size and number of trials, no statistical significance was detected, but future investigation with a larger sample will be performed to assess whether actual differences exist.

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THE TIME OF SLIP ONSET DURING STANCE INFLUENCES THE CHARACTERISTICS OF THE UNCONSTRAINED PERTURBATION

Corbin M. Rasmussen[1] & Nathaniel H. Hunt[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: cmrasmussen@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: **Poster Only**

INTRODUCTION

Lab-induced gait perturbations are a widely used strategy to study balance and prevent falls [see 1 for review]. A vast amount of this research has focused exclusively on slips that occur at heel-strike [ex. 2]. Recently, we developed the Wearable Apparatus for Slipping Perturbations (WASP), a device that administers slips uninhibited by mechanical limitations [3]. Due to its wearable and unconstrained nature, this device enables the evaluation of ecologically valid slip perturbations that occur at any point during stance which, to our knowledge, has not previously been explored. Therefore, the goal of this work was to investigate whether the timing of friction reduction during stance has a notable influence on the physical characteristics of the experienced perturbation.

METHODS

10 healthy, young adults (25.4±3.4 years, 1.75±0.07 m, 80.7±14.5 kg, 2 females) were consented for participation in the following IRB-approved study. All participants were outfitted with a compression suit, athletic shoes, a safety harness, a full-body marker set, and a pair of WASP devices. Subjects walked back and forth across an eight meter walkway at their self-selected speed. After a random amount of time between one and four minutes, a slip perturbation was triggered remotely by an attending researcher targeting either early (0-33%), mid (34-67%), or late (68-100%) stance phase. After each trial, participants were allowed a seated rest period, during which the activated WASP device was reattached to the proper shod foot. All subjects performed 12 trials. Trial duration, slip onset phase, and perturbed foot were all randomized prior to the start of the session. Marker trajectories were recorded at 120 Hz.

Gait events were determined using a coordinate-based method [4]. Slip onset was defined as the instant that the perturbed foot's horizontal velocity began to increase within the stance period that WASP was triggered, while slip cessation was either the next minimum in this velocity or the following toe-off (i.e. for late stance slips). All of the following attributes were computed in a center of mass (CoM) based coordinate system. Slip distances were calculated as the difference between the perturbed foot's CoM position at slip onset and cessation, while the peak horizontal velocity during this time was reported as the slip velocities. Slip direction was taken as the angle between the foot's CoM motion vector and the subject's heading.

A linear regression between each slip attribute and the time of slip onset, as well as Pearson correlation coefficients and coefficients of determination were calculated to assess the strength of each association. The critical alpha was set to 0.05.

RESULTS AND DISCUSSION

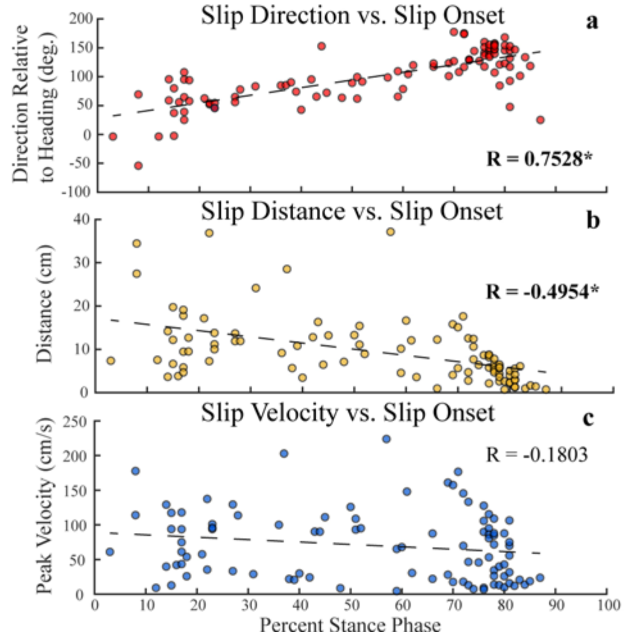

Figure 1: Linear regressions of the three examined slip attributes against onset phase.

A significant positive, strong linear relationship exists between slip onset time and slip direction ($r = 0.7528$, $p < 0.00001$, $n = 96$; Figure 1a), while a significant negative, moderate linear relationship exists between onset time and distance ($r = -0.4954$, $p < 0.00001$, $n = 96$; Figure 1b). 56.67% of the variance in direction is attributable to onset time ($r^2 = 0.5667$), while only 24.54% of the variance in distance is due to onset time ($r^2 = 0.2454$). The weak, negative linear correlation for onset time and peak slip velocity was not significant ($r = -0.1803$, $p = 0.079$, $n = 96$; Figure 1c), and onset time only explained 3.25% of the variance in velocity ($r^2 = 0.0325$). These results indicate that the timing of the perturbation impacts slip attributes that one must counteract to maintain balance, suggesting that using a range of onset times may offer a more comprehensive fall prevention program.

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Do older adults synchronize their strides to different visual stimuli?

Douglas Rowen[1], Luis Silva[1], Aaron D. Likens[1], Joao R. Vaz[1,2], & Nick Stergiou[1,3]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]Universidade Europeia, Lisbon, Portugal
[3]College of Public Health, University of Nebraska Medical Center, Omaha, NE USA
email: darowen@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: [**Poster**]

INTRODUCTION

Natural stride-to-stride fluctuations during walking display certain temporal properties and exhibit a power spectrum that is similar to that of pink-noise [1]. These properties change with aging and disease [2], and walking with cues from an external stimulus has been implemented in the rehabilitation of those pathological walking conditions. We argue that external cues should have a structure that mimics the fluctuations found in healthy walking. Previous research has shown that when pathologic populations walk to pink-noise based stimuli, their stride to stride fluctuations exhibit fluctuations similar to healthy walking [3]. This restoring capacity should be increased if the person and the stimulus are synchronized, which may be promoted in such fractal conditions. Here we further investigated how older adults synchronize their strides to three visual stimuli presented as pink-noise, white-noise, and non-variable.

METHODS

Six older adults (73.42±5.32 yrs.) walked around a 1/8th mile track. The subjects were asked to synchronize their steps to a visual bar displayed from a small monitor placed on a common pair of glasses. To measure stride time, footswitches (Noraxon, Scottsdale, AZ) were used. The temporal structure of the visual cues was adjusted using the subjects' self-paced mean and standard deviation. One trial of eight minutes for each stimulus was performed. Detrended Fluctuation Analysis (DFA) was used to determine the temporal scaling of the stride time intervals of each trial [4]. Synchronization index [5] was used to determine how well the subjects matched their steps with the visual cues. Friedman's ANOVA was used to assess differences between conditions for the DFA of stride time intervals. Pearson's coefficient of correlation and the coefficient of determination were calculated to identify if the fractal scaling differed between walking with the stimulus and walking immediately after the stimulus stopped would be related with the degree of synchronization during the stimulus.

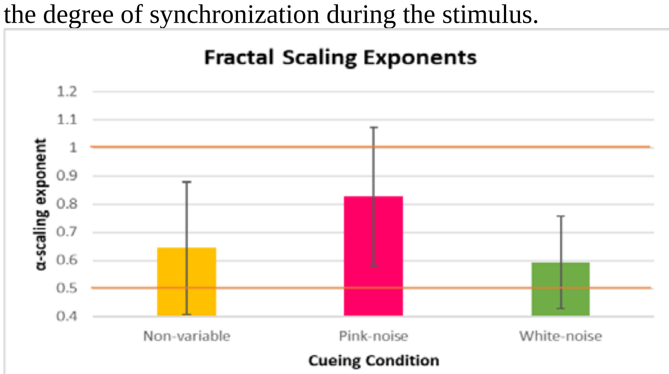

Figure 1: Scaling exponent for the three cueing conditions. A scaling exponent of 1.0 represents a pink-noise system, while a value of 0.5 represents a random or white-noise system. Values between 0.5 and 1.0 represent persistence.

RESULTS AND DISCUSSION

There was a significant difference between the cueing conditions ($\chi^2 = 6.33$;p=0.0421; Fig. 1). The pink-noise condition showed a strong correlation between ΔDFA and the synchronization index, while the other two conditions exhibited a weak correlation (Fig. 2).

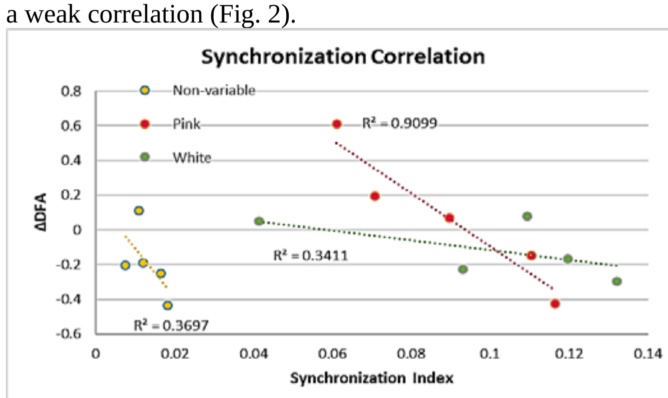

Figure 2: Correlation between the synchronization of the right heel strikes and the visual cues and the change in DFA scaling exponent from the cueing on to the cueing off for each of the three conditions. A positive ΔDFA value means that the scaling exponent was larger for the cueing on condition than the cueing off condition. The synchronization index varies between 0 and 1 with larger values indicating better synchronization to the cueing.

CONCLUSIONS

When walking to the pink-noise cue, subjects showed a higher correlation between the ΔDFA and the synchronization index. This means that individuals who synchronized well with pink-noise showed a larger fractal scaling when the cues were turned off. This could imply that individuals who had better synchronization were able to continue the effects into the non-cueing condition. Thus, methods to increase synchronization could be used to increase the aftereffects of cued walking.

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Passive exoskeleton assisted treadmill walking reduces duration and regularity of inter-limb coupling

Takashi Sado[1], BS, Zachary Motz, MS[1], Will Denton[1], MS, Jennifer Yentes[1], PhD., Mukul Mukherjee[1], PhD.
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: tsado@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: [**Poster**]

INTRODUCTION

Unilateral sensorimotor pathologies like stroke can lead to distorted linkage between the limbs, which can cause inefficient gait patterns. Device like a passive exoskeleton (self-powered) can be used to approach restoring a healthy gait. However, to our knowledge, no study has examined how the coordination between legs changes in exoskeleton assisted walking compared to regular walking.

Gait biomechanics, especially clinical biomechanics, generally incorporate the assessment of individual limbs and their characteristic gait patterns rather than focus on the coordinated behavior between the limbs and its impact on overall walking behavior. This is of critical importance in special populations, like stroke and unilateral amputees, where one half of the body has suffered pathology with characteristic effects distinctly different from the other half. Therefore, in these situations, the overall effect is one of an abnormally coordinated multi-segment unit. Unless appropriate variables are used to assess such abnormal behavior, the impact on therapy and rehabilitation may not be significant. Examples of such assessment instruments are cross recurrence quantification analysis (cRQA) and cross sample entropy (xSE).

Therefore, the current study aimed to investigate the change in coordination dynamics while walking at preferred walking speed with a unilateral exoskeletal device.

METHODS

Eighteen healthy young participants were randomly divided into EXO (n=9), and NO EXO (n =9) group. Individuals in EXO group wore a passive exoskeleton [2] on their right leg. Each participant performed 5 min normal walking at preferred walking speed (PWS) [1]. Step length, step time, and step width were measured.

In cRQA, mean length, percent determinism, and radius were measured by comparing the left and right lateral malleolus marker movements in anterior-posterior direction. For xSE, vector length was set to 2, and tolerance was calculated as average of standard deviation in each time series times 0.2. Statistical difference was examined via independent t-tests between EXO and NO EXO for all dependent variables (p<0.05).

RESULTS AND DISCUSSION

While there were no significant differences in spatial-temporal measurements between the two group, analysis of interlimb coordination showed significant group difference (Figure 1). The result of cRQA variables shows that although the duration of coordination was shorter and larger phase space needed in EXO group, the predictability of inter-limb coordination did not differ between the group. Higher cross entropy value indicates that walking with the device decreased the repeatability of the inter-limb coupling.

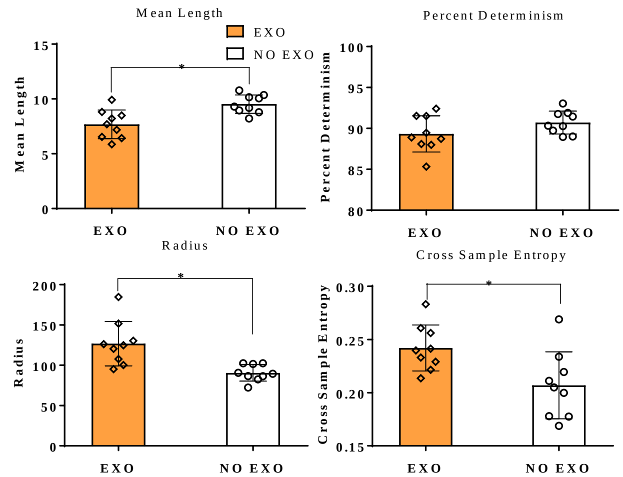

Figure 1 shows each cRQA variables and xSE between EXO and NO EXO. * represents significant difference between the two groups.

CONCLUSIONS

An unpowered device assisting the swing phase of gait reduced coordination duration and repeatability, which could be the characteristic coupled behavior of walking with this device, or that these are biomarkers of greater explorative behavior between the limbs. Such exploration may be useful for enhancing paretic propulsion in stroke survivors during gait coordination tasks. Future studies should investigate how the device changes the inter-limb coordination throughout the novel walking tasks, such as split-belt paradigm, and if inter-limb coordination in stroke survivors could be enhanced with exoskeleton-assistance.

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DEVELOPMENT OF A 3D PRINTED RADIAL ARTERY SIMULATION MODEL FOR ULTRASOUND GUIDED CATHETERIZATION

David Salazar[1], Nicholas Markin[2] & Jorge Zuniga[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]College of Medicine, Department of Anesthesiology, University of Nebraska Medical Center, Omaha, NE USA
email: dsalazar@unomaha.edu

Presentation Preference: (1) **Poster** or **Podium**

INTRODUCTION
Radial artery catheterization is a complex medical procedure that gives many medical students issues. This procedure can be done using either palpation guided techniques to locate the radial artery or with the use of an ultrasound. Currently, the only available ways to learn this procedure are within the operating room on a live patient, or through the use of an expensive palpation simulator model that many schools do not have access to. This lack of practice may result in students not feeling confident in their catheterization skills and cause increase time to cannulation or an increase in the total number of attempts. The use of ultrasound guided technique has shown to improve first attempt success rates [1]. 3D printing has been shown to be a useful tool in the development of low-cost anatomical accurate models for clinical education that can be used on multiple occasions [2]. The purpose of this study was to develop an ultrasound guided radial artery model that can be used as an educational model to improve students' catheterization skills.

METHODS
The model was created using a mold pouring technique. 3D Slicer was used to perform a segmentation of unidentified patient information. The segmentation was used to develop a 3D model of the radius, ulna, and carpal bones and then printed on a low-cost desktop 3D printer. A box mold was used to place the bone model, and the volume of the entire wrist was subtracted from the volume of the box to create an appropriate shape.

An echogenic gelatin was developed using a variation of the method previously described by Bude et al [3]. The gelatin was created using a combination of water, Knox gelatin, and Metamucil for the reflective fiber. An increased amount of fiber was used in order to more accurately mirror the results found in the ultrasound of a patient's wrist. This gelatin mixture was then poured into the open space of the box mold and encapsulated the 3D printed bones and arterial line replica. The model was allowed to cool over a 24-hour period and then removed from the mold (Figure 1).

After removal, the model was scanned using the GE VSCAN ultrasound device to observe echogenic properties. The metric used to determine the success of the model was the ability to identify the radial artery as well as echogenicity similar to that of human tissue. Water flow was introduced through the arterial line and when properly punctured would leak to indicate that the radial artery was accessed in the correct area and the catheter could be threaded through the artery. This method provides the user with immediate feedback on whether the procedure was done currently.

RESULTS
A low-cost replica of the wrist was successfully created using the procedure described in the methods. The components used to develop the model are inexpensive and can easily be purchased. The total price to produce each model is roughly $20 and can be used repeatedly to simulate the procedure of gaining access to the radial artery and properly inserting the catheter using the ultrasound to guide the movement.

In addition, after extensive usage the model can be melted down into a liquid form and then poured back into the mold to be reused. This will allow for hospitals to only necessitate the development of 1 model and then redeveloping the mold after enough uses.

Figure 1: Radial artery simulator model removed from the mold (Left). Scan showing the results of the ultrasound properties when the model is observed (Right).

FUTURE DIRECTION
The use of this simulator model has the potential to be useful as a method of Just-in-Time training for medical students directly before an operation, in order to improve performance within the operating room, as well as general practicing knowledge. We are currently in the process of applying for funding opportunities in order to observe the effect this model has on operating room performance.

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Synchronization between Stride Time Intervals and External Visual Cueing

Luis Silva[1], Aaron D. Likens[1], Douglas Rowen[1], João R. Vaz[1,3], Brian Knarr[1] & Nicholas Stergiou[1,2]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]College of Public Health, University of Nebraska Medical Center, Omaha, NE USA
[3]Universidade Europeia, Lisboa, Portugal

Presentation Preference: (2) **Poster**

INTRODUCTION

Synchronization is the adjustment of movement frequencies of two or more coupled oscillators when they interact. Humans naturally couple with simulated and biological motion, leading to entrainment. For example, this phenomenon is evident when someone taps to music. This natural ability could be useful to restore walking capabilities in patients with movement disorders because previous research shows (1) healthy walking exhibits a fractal pattern in terms of its stride-to-stride fluctuations and (2) people tend to reproduce the statistical properties (e.g., autocorrelation) of cueing signals. In this study, we argue that the ability to synchronize could be enhanced when the coupling systems match in their time-based statistical properties, such as those with a fractal patterns [1]. Therefore, we investigated whether the degree of synchronization depends on the statistical properties of external visual cues.

METHODS

Eight young adults (22.3±1.3 yrs) walked over ground to three external visual cues: a non-variable, a fractal, and a random one with no apparent temporal structure. Participants synchronized their steps with a continuous, vertically moving bar displayed on a small video monitor connected to a pair of glasses (Vufine®, Sunnyvale CA, USA). Three methods were used to analyze synchronization between stride time intervals and time intervals of the visual cues: synchronization index [2], spectral coherence, and multifractal detrended cross-correlation analysis (MFDxA) [3]. For the latter, the positive q-order equal to two was chosen because when q is equal to two in MFDxA, it is the same that have the original detrended cross-correlation coefficient. Friedman's test was used to assess omnibus differences among stimuli. Dunn's test was used to perform pairwise comparisons.

RESULTS AND DISCUSSION

Our results showed that the non-variable visual cueing suppressed synchronization in agreement with previous research (Fig 1; [4]).

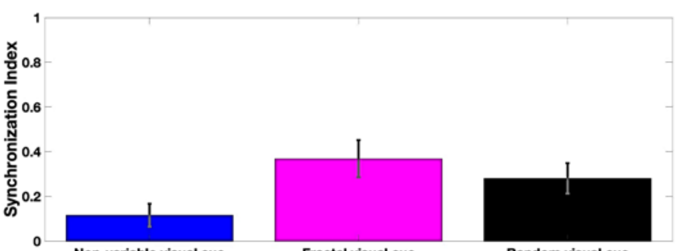

Figure 1: Synchronization index between stride time intervals and beat time intervals of the metronomes as a function of cue type. Synchronization index is based on Shannon entropy and measures the degree of synchronization between two time series. It can vary between 0 and 1. A synchronization index of 1 means a perfect synchronization.

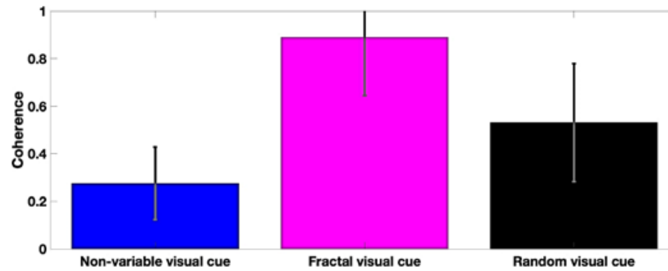

Figure 2: Coherence between stride time intervals and visual cueing time intervals as a function of cue type. Coherence measures the degree of correlation between two time series in the frequency domain and varies between 0 and 1. A coherence of 1 means a perfect correlation between time series.

Significant differences were found among stimuli ($\chi^2 = 12.29; p = 0.002$), for the synchronization index, coherence measure, and the q-dependent cross-correlation of MFDxA (Fig. 1-3). Pairwise comparisons were also consistent among methods showing differences between the non-variable and the fractal visual cue ($p < 0.05$).

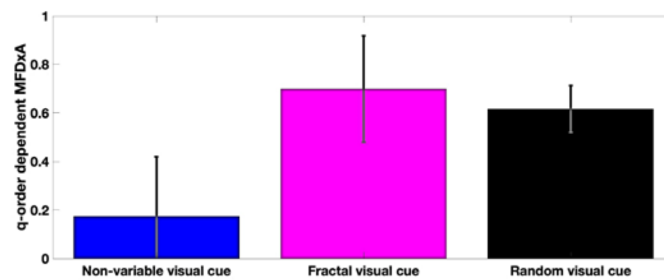

Figure 3: The q-order cross-correlation of MFDxA (q = 2) measures fluctuations between stride time intervals and visual cueing time intervals. The q-dependent cross-correlation varies between -1 and 1 for q > 0. Here was considered the absolute correlation. A q-dependent cross-correlation of 1 means a perfect correlation between the fluctuations of two time series.

CONCLUSIONS

Coordination with non-variable stimuli was particularly poor, possibly due to its dissimilarity with natural walking patterns. The stride-to-stride fluctuations of healthy gait exhibit time-based proprieties that enhance coupling with the fractal, and potentially the random, but not with the non-variable visual cue.

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Multifractal Analysis of Visually Cued Stride Intervals

Luis Silva[1], Aaron D. Likens[1], Doug Rowen[1], João R. Vaz[1,2], Brian Knarr[1] & Nick Stergiou[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]Universidade Europeia, Lisboa, Portugal

Presentation Preference: **(1) Poster** or **Podium**

INTRODUCTION

The information of one system can be changed when coupled with another when both networks generate 1/*f* fluctuations, as demonstrated by the complexity matching hypothesis [1]. The goal of external cueing is to exploit this tendency to restore behavioral 1/*f* fluctuations. Detrended Fluctuations analysis (DFA) is commonly used to quantify those fluctuations. However, DFA assumes the presence of monofractal characteristics, an overly restrictive assumption for human behavior. That is, monofractal analysis assumes that fractal scaling is independent of time and space. In contrast, the multifractal generalization of DFA (MFDFA; [2]), takes into consideration temporal and spatial variations of fractal scaling. We investigated multifractal characteristics of stride time intervals when people coordinate their steps with external visual cues presented in a non-variable, a variable-pink noise, and a variable-white noise fashion.

METHODS

Eight young adults (22.3±1.3 yrs) walked overground while synchronizing their steps to 3 types of visual cues. The visual cues consisted of a continuous, vertically moving bar displayed on a device connected to glasses (Vufine®, Sunnyvale CA, USA). We conducted MFDFA with a q-order interval between -5 and 5 with the length of 101 points. Our hypotheses were that (1) the generalized Hurst exponent of small ($Hq^{(-)}$) and large ($Hq^{(+)}$) fluctuations, the Lipschitz–Hölder exponent at maximum spectrum (hq^{max}; Fig. 1), and the multifractal spectrum width (△hq), would differ among the three cueing categories, and (2) that similar results would be found in the cross spectral parameters of multifractal detrended cross-correlation analysis (MFDxA) [3-4].

RESULTS AND DISCUSSION

This study comprises two dimensions of analysis. One approach seeks to distinguish separately segments with small and large fluctuations in stride intervals for each stimulus. The other focuses on the coupling between stride time interval and stimuli.

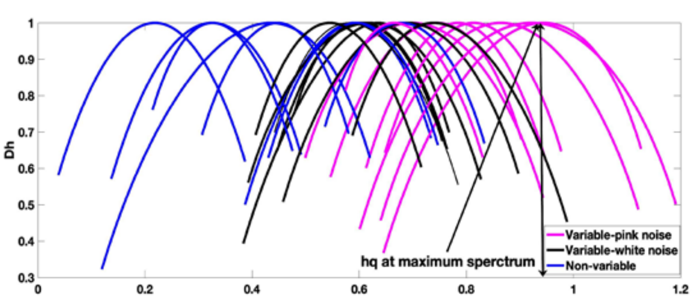

Figure 1: Multifractal Spectra ([-5,5] interval) for the three stimuli: fractal (pink), white noise (black), and periodic (blue) for all subjects. Dh – q-order singularity dimension; hq – Lipschitz–Hölder exponent.

The spectrum width did not differ among cue types; however, $Hq^{(+)}$ did differ as a function of cueing, with the pink noise (0.81 ± 0.08) condition producing larger $Hq^{(+)}$ than the white noise (0.59 ± 0.07) or the non-variable (0.45 ± 0.19) condition (Table 1). Results for hq^{max} and the $Hq^{(-)}$ were similar. The q-order fluctuations for variable-pink noise coupling tended to converge at large scales, as expected in the case of multifractality (Fig. 2). This tendency was less evident in variable-white noise and non-variable coupling which were more constant over scales.

Table 1. Friedman ANOVA and Dunn's test pairwise comparisons for stride time intervals.

	χ^2	*p*	Pairwise (*p*)
$Hq^{(-)}$	14.25	< 0.001	Pink – Non-variable (< 0.001)
$Hq^{(+)}$	13.00	0.002	Pink – White (0.033) Pink – Non-variable (<0.001)
hq^{max}	14.25	< 0.001	Pink – Non-variable (< 0.001)
△hq	0.250	0.883	--
$Hq_{xy}^{(-)}$	14.00	< 0.001	Pink – Non-variable (< 0.001)
$Hq_{xy}^{(+)}$	16.00	< 0.001	Pink – Non-variable (< 0.001)
Hq_{xy}^{max}	14.00	< 0.001	Pink – Non-variable (< 0.001)
$△hq_{xy}$	3.71	0.156	--

xy means coupling parameters from multifractal detrended cross-correlation

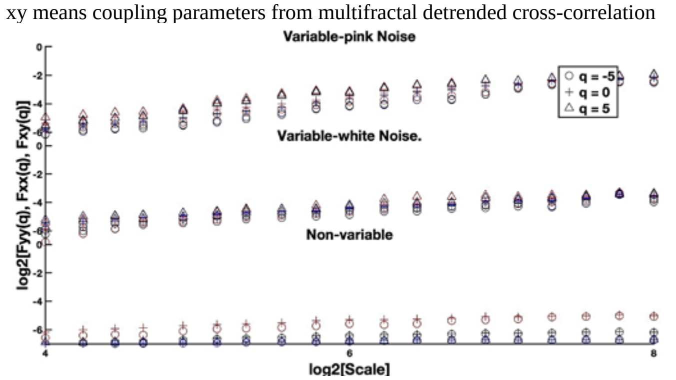

Figure 2: Example of subject 2 of Multifractal Detrended Cross-correlation Analysis. Power-law scaling in Fxy (black), Fxx (red) and Fyy (blue) with respect to scale for q-order of -5, 0, and 5.

CONCLUSIONS

The local adjustments that occur in healthy gait do not correspond to the non-variable or the white-noise cueing. There are not enough local phase adjustments to enhance coupling with these cueing conditions. These stimuli are not compatible with the fluctuations present in healthy gait.

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ACKNOWLEDGEMENTS

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THE EFFECT OF A NOVEL TASK INTERVENTION ON GAIT VARIABILITY IN OLDER ADULTS

Andreas Skiadopoulos, Katherine Allen & Nicholas Stergiou
Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: nstergiou@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: [**Podium Only**]

INTRODUCTION

Falls are a leading cause of injury among older adults and most often occur during walking [1]. Increased step width variability was identified as a factor that increases the risk of falling in older adults [2]. Therefore, an intervention for reducing increased step width variability may consequently reduce fall risk for older adults. We propose that healthy older adults with age-related gait abnormalities, can reduce step width variability by performing lateral stepping training [3].

METHODS

Fourteen older adults aged 65+ (3m; age: 70 ± 3 yrs.; height: 166.1 ± 10.9 cm; mass: 72.6 ± 12.6 kg) were recruited for this study. The Mini-Mental State Examination showed high scores (>28) for all participants. At the Baseline assessment, the participants performed a three-minute treadmill trial at their self-selected comfortable speed. For the data collection on the treadmill, participants wore retroreflective markers on the top of the second metatarsal joint and posterior heel. Continuous motion of feet was tracked by a 17-camera high-speed motion capture system (Motion Analysis Corp.) at 100 Hz. Following Baseline assessment, the participants underwent an overground lateral stepping training three times a week for six weeks, resulting in 18 sessions. Each session consisted of 30 minutes of lateral stepping. Participants stepped laterally across a 10m section on an indoor track, changing direction at the ends thus alternating lead and lag legs. Three minutes of lateral stepping was alternated with at least one minute of rest. They informed that they could increase their pace at the start of each session but may not decrease it at the next session. This promoted continued learning and prevent any plateau effect.

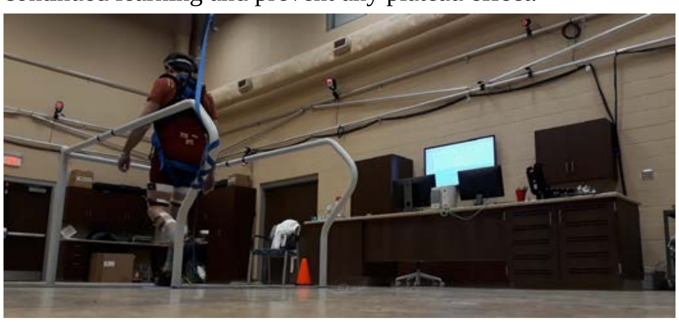

Figure 1. Treadmill walking during Baseline assessment.

Similar to the Baseline assessment, kinematics data were collected after completion (Post) of the training, and six-weeks following completion (Retention). Self-selected speeds were used for all trials at each assessment. The raw 3D marker trajectories were low-pass filtered (6 Hz). After determining gait events using proper MATLAB code, the step width (i.e., mediolateral distance between the locations of the sequential left and right heel strikes), step length (i.e., anteroposterior distance between the locations of the sequential left and right heel strikes), stride time (e.g., the time between two consecutive ipsilateral heel strikes), and the stance time (e.g., the time elapse during the stance phase of one leg) were measured. The standard deviation used to express the variability.

RESULTS AND DISCUSSION

The six-week lateral stepping intervention significantly decreased the step width variability in older adults. These results were retained for six-weeks after the completion of the intervention (Figure 2). There is no significant change from baseline at post assessment for stride time, stance time variability, and step length variability parameters. However, all gait variability parameters showed a decreasing trend after the intervention, although no statistically significant, indicating no harmful effects. Importantly, variability decreased significantly for all parameters from Baseline at Retention assessment.

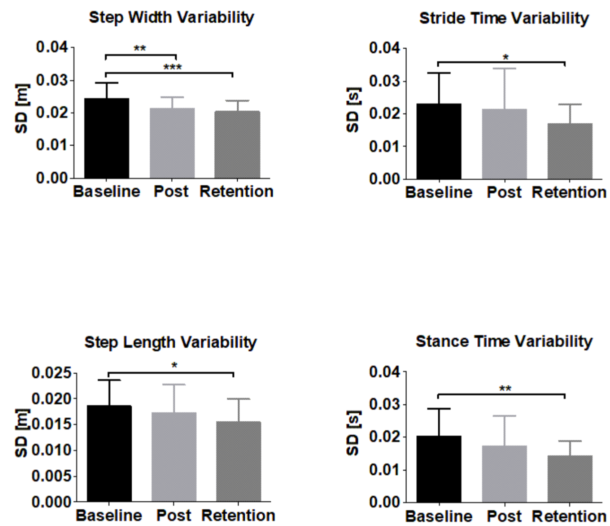

Figure 2: The intervention significantly reduced step width variability and the effects were retained for the six-week period following the completion of the training. Importantly, stride and stance time, and step length variability decreased from Baseline at Retention assessment ($p<.05$*; $p<.01$**; $p<.001$***).

CONCLUSIONS

The results point strongly towards a transfer effect from the lateral stepping gait training to typical forward walking. In addition, the results did not show any harmful effect of the lateral stepping training on the gait variability. The results strongly support the efficiency of the lateral stepping gait training to decrease gait variability in older adults.

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ACKNOWLEDGEMENTS

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SUBTHRESHOLD VIBRATION INFLUENCES THE POSTURE AND GAIT OF TRANSTIBIAL AMPUTEES

Ian Sloan [1], Jenny A. Kent[1], Aaron Likens[1], Kota Z. Takahashi[1], Nicholas Stergiou[1, 2]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]College of Public Health, University of Nebraska Medical Center, Omaha, NE USA
Email: csloan@unomaha.edu

Presentation Preference: (1) **Poster** or **Podium**

INTRODUCTION

Amputation below the knee causes a person to lose important pathways to the central nervous system used in sensation and balance [1]. A lack of sensation in the residual limb [2] has been shown to be a factor in poor balance [3]. The 'stochastic resonance' phenomenon, where the addition of subthreshold noise enhances detection of a weak stimulus, has been shown to improve sensation and subsequently balance [4]. White noise has been typically used in previous stochastic resonance studies; a random signal with equal intensity throughout its frequency spectrum. We also investigated a pink noise (1/f) vibration structure based on the fact that it is more often seen in natural processes [5]. We hypothesized that stimulation would improve control of the prosthesis, which would decrease step variability during walking and increase postural control. Further, we expected the change to be greater with the pink noise stimulation when compared with the white noise.

METHODS

Fourteen participants with a unilateral transtibial amputation (height 1.79m±0.07, weight 100.3kg±15.6, age 59.7±15.0) completed a balance test as well as overground and treadmill walking trials, under three different vibration conditions: None, pink noise, and white noise. Vibration was provided by a vibrating device set on the residual thigh. The three conditions were randomized and kept from the subject. The vibration thresholds were set at the beginning of the session and then set to 60-90% of this threshold to ensure that the participant could not feel the device. Kinematic data from all walking trials was collected at 100Hz, and balance testing was collected at 60 Hz, with a twelve-camera motion capture system (Motion Analysis Corporation, Santa Rosa, CA). Averages and standard deviations for all kinematic variables were computed Visual 3D (C-Motion, Germantown, MD) for all three conditions. A series of linear mixed effects models was conducted in order to understand the effects of vibration condition on various kinematic variables obtained from walking (treadmill and over ground) and quiet standing. Baseline models were 'intercept-only' models. Final models contained fixed main effects and interactions of noise type and diabetic threshold (above and below) and random intercepts. Overground and treadmill walking trials were analyzed separately, as distinguishing between those conditions was not of central interest.

RESULTS AND DISCUSSION

Walking. Analysis of sound leg step length variability during over ground walking trials revealed that the white noise condition produced lower step length variability than the none condition (Fig. 1; *Estimate*=-.003, *SE*=.001, *p*=.034). Also, above threshold participants produced greater sound leg step length variability than those participants classified as below threshold (Fig. 1; *Estimate* = -.004, *SE* = .002, *p* = .008).

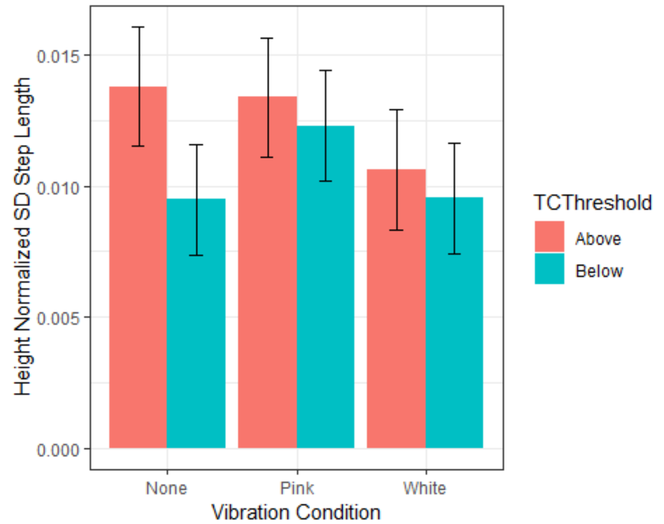

Figure 1. Bar chart of sound leg step length variability during over ground walking as a function of vibration condition and diabetic threshold. Error bars reflect 95% confidence intervals. Step length variability was height normalized.

Quiet standing. The analysis revealed that the pink noise condition reduced mediolateral COP range when compared with the none condition (Fig. 2; *Estimate* = -.004, *SE* = .002, *p* = .013. Similarly, mediolateral RMS COP displacement was also lower in the pink noise condition than the none condition (*Estimate* = -.001, *SE* = .0002, *p* = .008.

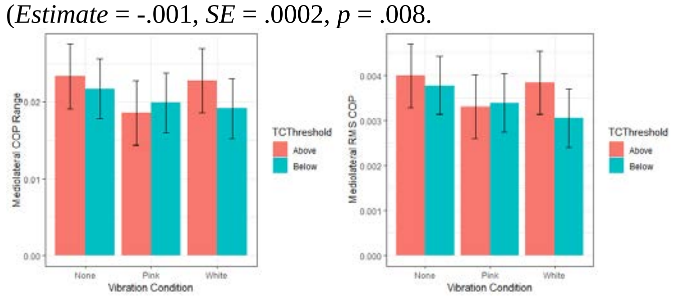

Figure 2. Bar charts of mediolateral COP range (left) and RMS displacement (right) during quiet standing as a function of noise and diabetic threshold. Error bars reflect 95% confidence intervals. Range and RMS were height normalized.

CONCLUSIONS

In conclusion, the addition of subthreshold vibration has shown to have an effect in amputee gait and posture. During quiet standing, results show that pink noise subthreshold vibration has the ability to decrease sway in the mediolateral direction for all amputees. The weaker results during walking indicate that an alternative option should be explored for use during gait.

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ACKNOWLEDGEMENTS

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ALTERING ASPECTS OF GAIT THROUGH THE USE OF PACING SIGNALS: A PILOT STUDY

Joel H. Sommerfeld[1], Aaron D. Likens[1], Nick Stergiou[1,2]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]College of Public Health, University of Nebraska Medical Center, Omaha, NE USA
email: jsommerfeld@unomaha.edu, web: https://www.unomaha.edu/college-of-education/cobre/

Presentation Preference: (1) **Poster** or **Podium**

INTRODUCTION

Walking studies have used isochronous pacing signals in replicating effects of aging and regulating gait parameters in pathological populations [1,2]. While isochronous pacing signals have been shown to improve aspects of gait such as velocity and stride length, they do not accurately represent healthy walking patterns. Fractal ($1/f^{\alpha}$) pacing signals are more appropriate and have been shown to produce gait characteristics, in older populations, similar to those exhibited by healthy controls, and thus demonstrating importance for rehabilitation [3]. The opposite can also occur when a random, $1/f^{0.5}$ pacing signal is used. By having healthy individuals walk to pacing signals which replicate the gait of older adults, comparisons between the two demographics are able to be drawn. Despite prevalent use of pacing signals in basic experimental and rehabilitative settings, more research is needed to understand the features that are being tuned into as the participants walk. We hypothesize that the probability distribution of the stride time intervals is an important consideration when creating a pacing signal.

METHODS

Four participants (mean ±SD; age 23.5±1.73, 3F) walked for 15 minutes at their self-selected pace in order to be able to customize the pacing signals to the individual. Participants then completed four trials of paced walking with different stride time interval probability distributions. These trials were walking to a pink noise pacing signal (PPS), shuffled pink noise pacing signal (SHPS), Gaussian distributed random pacing (GRPS) and a uniformly distributed random pacing signal (URPS). The pacing signals were designed to differ increasingly from healthy walking to a more random walk. These were given to each participant in a randomized order.

Pacing signals were shown to the participants via HDMI glasses (VUFINE. Sunnyvale, CA) and the corresponding heel strike data was collected using individual Noraxon footswitches (Noraxon USA, Inc., Scottsdale, AZ). The cueing signal was continuous to allow the participants to follow and synchronize more easily. The display, which the participants viewed, consisted of two stationary bars at the top and bottom of the screen. A third, timing bar moved vertically between the two stationary bars. Participants were instructed to synchronize their right heel strikes with the timing bar reaching the top stationary bar and turning red. Participants walked for approximately 15 minutes, following the pacing signal. This allowed for 700 strides, of which the first and last 50 strides were discarded during data analysis. Between each trial, participants rested for ≥ 5 minutes.

RESULTS AND DISCUSSION

The DFA α scaling exponent was calculated on heel strike data from the self-paced trial and trials using the four pacing signals (PPS, SHPS, GRPS and URPS; Fig. 1). A one-way repeated measures ANOVA found no significant differences among the signals, likely due to small sample size of participants. Increasing sample size may reveal reliable differences.

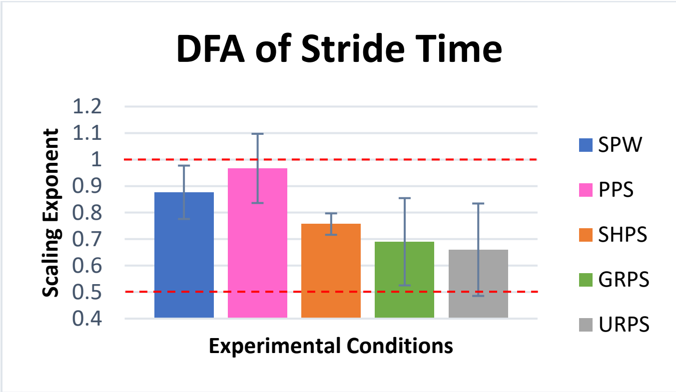

Figure 1: Bar graph of α as a function of pacing signal. Dashed lines are theoretical α values for healthy (1.0) and pathological (0.5) adults. The trend suggests that (1) PPS produces theoretically ideal stride fluctuations, whereas (2) increasing dissimilarity between pacing signal and natural gait produces fluctuation patterns more consistent with pathological gait.

CONCLUSIONS

The results (Fig. 1) provide preliminary support for the hypothesis that the probability distribution of a pacing signal does affect the DFA α scaling exponent. In trials where the probability distribution most closely resembled healthy walking, α tended to be slightly higher. On average, α decreased as the probability distribution of the signal varied more greatly from the distribution seen in healthy walking. This suggests that the probability distribution of signals should reflect the natural task dynamics as much as possible.

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APPLICATIONS OF ANTIMICROBIAL 3D PRINTING MATERIALS IN SPACE

Michael Thompson[1], Jorge Zuniga[1]
[1]Department of Biomechanica, University of Nebraska at Omaha, Omaha, NE USA
email: michaelthompson@unomaha.edu
Presentation Preference: [3) **Poster Only**]

INTRODUCTION

Life in space can weaken the immune system. Current flight experiment data [1] indicates alterations in microbial virulence and astronaut immune function during spaceflight suggesting an increased risk of infectious disease during spaceflight missions. Some crew members also experience chronic hypersensitivity reactions due to immune system dysregulation potentially limiting the longevity of space mission [1]. In combination with potential host susceptibility due to dysfunction in the immune system, infectious disease risk may be significantly greater than in the spaceflight environment than in normal workplace settings [1].

METHODS

Additive manufacturing has already been proposed and implemented as a suitable technology for manufacturing medical devices in space to fulfill the orthopedic needs (orthosis) of crew members with promising applications in onsite emergency care, such as manufacturing of surgical instruments. However, the bacterial risk in space remains, making the use of antimicrobial 3D printing filament a necessity for future human spaceflight.

Copper compounds have shown a high potential for the development of medical devices with powerful antibacterial properties at a low cost [3]. PLACTIVE™ is an antibacterial 3D printing filament (1% Antibacterial Nanoparticles composite, Copper3D, Santiago, Chile) has shown to be up to 99.99% effective against Staphylococcus aureus and Escherichia coli [3] (Table 1). The manufacturing process of antimicrobial medical devices using a biocompatible antimicrobial 3D printing filament is described in the figure below.

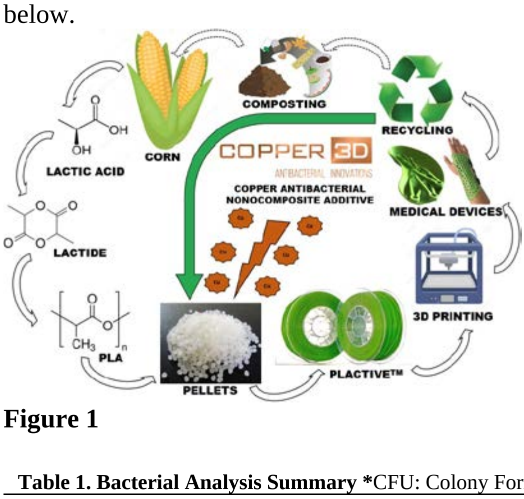

Figure 1

RESULTS AND DISCUSSION

PLACTIVE™ has been used to successfully manufacture antimicrobial 3D printed finger orthoses and surgical instruments. The most common injuries among astronauts are finger injuries [2]. These injuries can lead to permanent deformities and function loss. Additive manufacturing using antibacterial materials can be used for situational and custom production of finger orthoses and surgical instruments, all while reducing bacterial risk. The utilization of additive manufacturing in space eliminates the logistical inventory issues while the antimicrobial properties eliminate the need for on board sterilization techniques [2].

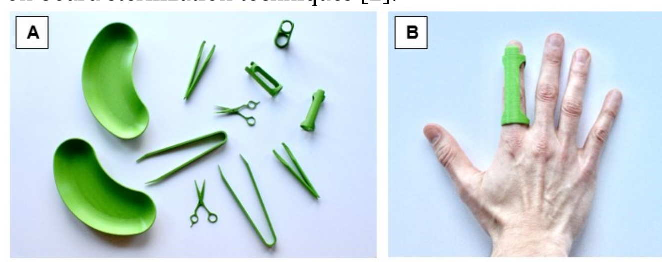

Figure 2

CONCLUSIONS

The development of antibacterial 3D printing filaments with thermoforming capabilities have the potential of revolutionize patient care of crewmembers. Potential applications are not limited to only medical devices, but any other non-medical object critical to the crewmembers, such as sound protection panels. Medical devices containing bacteria eliminating properties will remove the need for sterilization techniques that require additional transportation space increasing the overall logistic burden to conserved space. The unprecedented accessibility of 3D printing technology and the implementation of antibacterial 3D printing filament to manufacture medical devices is not only critical during spaceflight missions, but has a promising potential to a wide range of clinical applications on earth and on the civilian populations revolutionizing patient care.

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Table 1. Bacterial Analysis Summary *CFU: Colony Forming Unit

Laboratory	Inoculum (initial load, CFU/ml)	Log$_{10}$ Reduction at 24 hours	Reduction (%)
1	Methicillin-resistant Staphylococcus aureus (7.10E+9)	1.65	98.95
	Escherichia coli (3.33E+9)	1.32	95.03
2	Staphylococcus aureus (6.3E+5)	5.7	99.99
	Escherichia coli (9.3E+5)	4.6	99.99

Adaptations of static control through the application of prisms

Panagiotis V Tsaklis[1,3,4], Aikaterini Ziaka[1,2] and Ioannis Giakas[2]

[1]Department of Physiotherapy, Alexander Technological Educational Institute of Thessaloniki, Hellas
[2]Department of Physical Education and Sports Sciences, University of Thessaly, Hellas
[3]Department of Molecular Medicine and Surgery, Karolinska Institute, Sweden
[4] Department of Biomechanics, University of Nebraska at Omaha, USA
email: tsaklis@phys.teithe.gr

Presentation Preference: [**Poster Only**]

INTRODUCTION

Plasticity of neurological mechanisms on visual perception on space constitutes an important tool for neurorehabilitation. The body's stance can be alter and adapt, by the use of rotary visual prisms and the neurorehabilitators can influence the perception of space and the functional behaviour of patients with neuropathology,through movement and postural control re-education.

METHODS

In the present study participated 14 children (aged 7-10 years). Data collection was performed using force plates (BERTEC 40x60 at 1kH) during a quite bipedal standing position (for the investigation of the Weight shift and BW% distribution changes) and a "sit to stand" dynamic task (for the investigation of the balance control and recovery), before, during and after the use of prisms

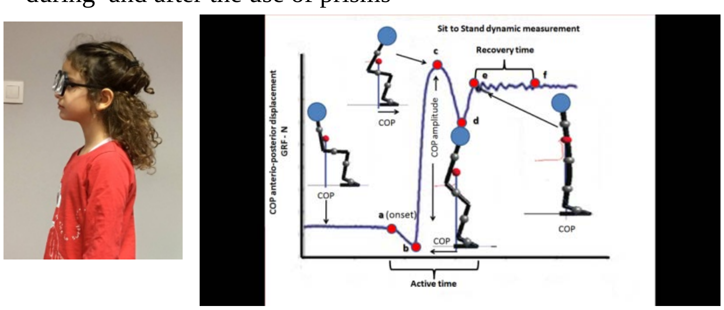
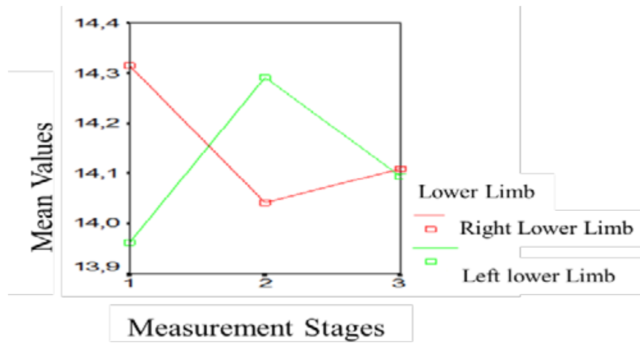
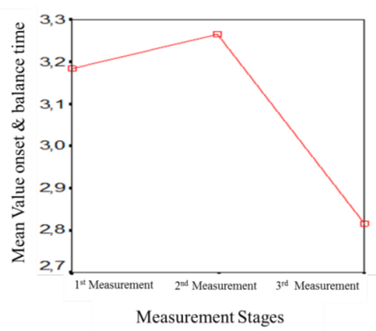


Figure 1: Use of prisms and "sit to stand" dynamic balance task

RESULTS AND DISCUSSION

It was observed an interaction and clear effect on the body weight distribution (BW%) during standing position and there was a trend for maintenance after prisms application which led to higher degree of symmetry in posture. For the sit to stand task, the results showed variations between the three measurements with respect to *total execution time*, with a reduction for all the participants, but with no statistically significant deference (p> 0, 05).





Figures 2&3: Body Weight distribution (Kg) and dynamic balance task (sec), before - during and after the prisms application

CONCLUSIONS

This study showed that the body weight distribution and the dynamic stability of children aged 7-10 years can be positively altered with the use of prisms, but more research and bigger sample is needed in order to assess the maintenance of prisms' influence.

	1st before prisms		*2nd during prisms*		*3rd after prisms*	
	R-leg	*L-leg*	*R-leg*	*L-leg*	*R-leg*	*L-leg*
N	*14*		*14*		*14*	
BW%	***50,71***	***49,29***	***49,26***	***50,74***	***50,03***	***49,98***

Table .1: BW% distribution, before – during – after prisms

DEVELOPMENT OF WEARABLE APARATUS FOR SLIP PERTURBATIONS

Andrew Walski[1], Corbin Rasmussen[1] & Nathaniel Hunt[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
awalski@unomaha.edu, cmrasmussen@unomaha.edu, nhunt@unomaha.edu

Presentation Preference: [(3) **Poster Only**]

INTRODUCTION

Studying balance and recovery skills from slip perturbations can be a very difficult task.[1] A slip perturbation must be administered at specific points within the gait cycle without the subject knowing when it is going to occur. We have addressed this complication by developing a wearable apparatus for slip perturbations (WASP). The WASP is a device worn over the shoe that provides adequate traction for the wearer to walk normally but takes that traction away the instant a slip perturbation needs to be administered. The basic Design of the WASP consist of a detachable sole with a plantar surface of rubber and a dorsal surface lined with PTFE. A regular athletic shoe rests atop of the dorsal surface of the sole and is held in place by nylon straps and fluorocarbon monofilament. These straps ultimately are held together at a single point where the release mechanism allows for all the straps to be released on command. The first functional device used motorcycle boot soles that were durable but heavy. The release mechanism used nichrome wire to cut the fluorocarbon monofilament with heat. This made the release time delayed and it was difficult to hit the target release time. The device was also heavy, making it less ecologically valid.

METHODS

The current version of WASP uses a cam and pin mechanism to release the sole. Instead of cutting, the pin provides a single attachment point that can rapidly recede into a housing to release the monofilament that holds the straps together. The pin is manipulated by a spring and a cam. The cam is spiral shaped with a 5-millimeter drop. The cam pushes against the pin that is opposing the cam with the help of a spring. The cam stops right before the 5-milimeter drop and does not turn until wirelessly commanded to by the user. When the command is sent the cam turns and the pin immediately recedes into the housing. This version is lighter because it uses a 1/32’’ thick rubber sheet for the sole instead of the motorcycle boot soles. The rubber sheet is cut and sewn in a shape that conforms to the shape of the subject’s shoe and wraps the lower portion of the shoe in a layer of rubber.

The release speed was tested by filming the release with a high-speed camera at 1000 Hz. A led was wired into the circuitry to light up when the release mechanism was activated. The number of frames from the moment the light turned on to the point the release mechanism releases the straps is the release time. Each version of WASP went through 12 trials and the average release time and standard deviation were taken.

RESULTS AND DISCUSSION

Old WASP New WASP

Figure 1: Visual Comparison

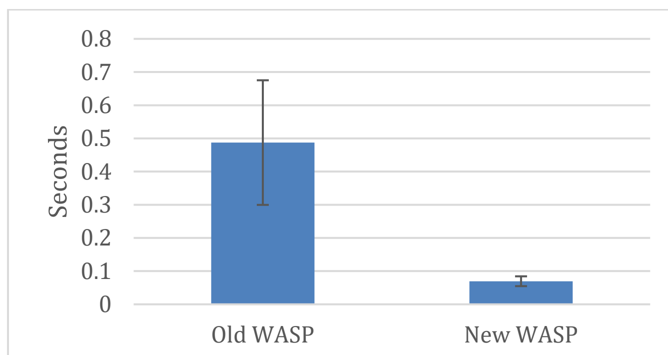


Figure 2: Average Release Speed

The old WASP had an average release time of (0.482 +/- .188s) while the new WASP had a much faster release time of (0.070 +/- .015s) (Figure 2). The new WASP is 45.8% lighter than the old WASP because of change in materials of the outsole. The new WASP is faster and lighter than its predecessor.

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Table 1: Weight Differences between old and new WASP

*All units in grams	Old Version	New Version	Percent Change
Release Component	154	247	60.4%
Outsole Component	538	128	-76.2%
Total	692	375	-45.8%

DAILY ACTIVITY IN PEOPLE WITH PARKINSON'S DISEASE PRESENT LESS REGULAR PATTERNS

Connor Wicks[1], Shane Meltz[2], Vivien Marmelat[2]
[1]College of Arts and Sciences, University of Nebraska at Omaha, NE USA
[2]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
email: sc2d.labuno@gmail.com

Presentation Preference: **Poster only**

INTRODUCTION

Parkinson's disease (PD) disturb the circadian rhythmicity [1], which can be assessed using activity monitors. Previous studies [2] highlighted that people with PD present overall activity changes (i.e., 'how much activity?'), but did not determine changes that may be present within the circadian system and temporal organization of daily activity [3] (i.e., 'how is the activity distributed?'). It has been shown that the suprachiasmatic nucleus (SCN) –which controls circadian rhythm –contribute to the patterns of activity across a wide range of time scales [3]. Neurodegenerative disease such as Alzeihmer's disease impact the distribution of daily activity, which become less predictable. Our first goal was to determine if PD changes the pattern of daily activity. Our second goal was to determine the relationship between fractal regulation of daily activity and standardized clinical tests for people with Parkinson's.

METHODS

We recruited 83 total participants: 27 people with PD, 32 healthy elderly (HE), and 24 healthy young (HY).

We conducted a series of self-reported questionnaires that included medical history, Modified Fall Efficacy scale (MFES), Geriatric Depression Scale (GDS), Lawton Instrumental Activities of Daily Living, Montreal Cognition Assessment (MoCA), Timed Up and Go Test (TUG), and The Fullerton Advanced Balance Scale (FAB). There were two tests that were only conducted with participants with Parkinson's and they were the Hoehn & Yahr Scale (H&Y) and the Freezing of Gait Questionnaire (FoG). After the questionnaires participants were given a activity monitor (Actigraph GT9X) put on a wrist band that they wore on their non-dominant wrists. The activity monitor would activate the day after the questionnaires at 8 AM and continued for seven straight days. Vector magnitude of activity (VMA, i.e., the 'amount' of activity) was extracted in bouts of 15 seconds for the seven days, leading to 5760 bouts of VMA per day per individual. These bouts were subsequently summed 30-sec, 1-min, 10-min, 30-min, and 1-h intervals. We calculated the mean and the Jensen-Shannon Divergence (JSD) [4] of VMA for each participant and for each of the time intervals. JSD is a measure that allows us to identify daily activity patterns and the persistence of each individuals' patterns at the different time scales. One-way analysis of variance's (ANOVA) were used to compare the means and JSD of activity levels between groups, for each of the different bout lengths. Post hoc analysis used Turkey's multiple comparison's tests. Pearson's correlations were used to assess the relationship between JSD and the mean at each of the intervals, for each group, and between JSD or mean and each of the questionnaires and tests.

RESULTS AND DISCUSSION

JSD values were significantly greater (i.e., less similar day-to-day) for the PD group compared to the HE and HY groups, for the 15-sec, 30-sec and 1-min intervals ($p<.001$). Consistent with previous literature, the PD group was also less active on average ($p<.001$). There was a consistent negative relationship between JSD and mean activity for all groups (Figure 1), for the 15-sec, 30-sec and 1-min intervals ($p<.001$). This suggests that the more active people also present more regular patterns of activity. JSD was also negatively correlated with previous fall in the PD group ($r=-.401$, $p=.038$), suggesting that fallers present more regular patterns of activity. This finding may seems surprising: JSD correlate both with the amount of activity and with the number of previous falls, but there were no significant correlations between number of falls and total (mean) activity. Future studies should determine the interactions between total daily activity, JSD and falls.

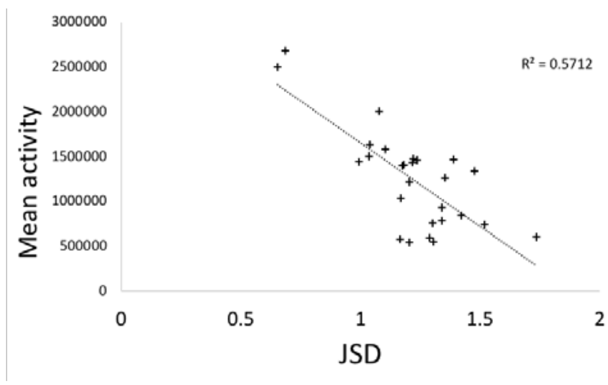

Figure 1. Correlation between JSD and mean activity at 15-sec intervals for the PD group.

CONCLUSIONS

Our results suggest that the more active people have a more regular pattern of activity, a finding consistent across populations. Our results raise important questions regarding the interactions between the total amount of daily activity, the temporal organization of activity and falls in people with PD.

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DIFFERENCES IN UPPER EXTREMITY AND TORSO CONTROL AFTER WHEELCHAIR RECONFIGURATION

Casey Wiens[1], Ian M. Russell[2] , Philip S. Requejo[3], Jan Furumasu[3], and Jill L. McNitt-Gray[1,2]
[1]Department of Biological Sciences, University of Southern California, Los Angeles, USA
[2]Department of Biomedical Engineering, University of Southern California, Los Angeles, USA
[3]Rancho Los Amigos National Rehabilitation Center, Downey, CA, USA
email: cwiens@usc.edu
Presentation Preference: **Poster** or **Podium**

INTRODUCTION

Clinical guidelines for wheelchair (WC) seating focuses on the individual's posture, pressure distribution, and stability requirements during activities of daily living [1]. Ongoing clinical research investigating the effect of WC seating on manual WC propulsion mechanics confirms that modifications to WC seating alter multiple factors known to affect posture, stability, and upper extremity joint kinetics in individuals with paraplegia [2,3]. We hypothesized that modifications to WC configuration will also affect control of the upper extremity and trunk during manual WC propulsion in order to satisfy system stability and impulse generation requirements during manual wheelchair propulsion in the community.

METHODS

Individuals with paraplegia (T2-L3, 28 male, 2 female) without shoulder pain volunteered to participate in accordance with the Institutional Review Board. Participants performed self-selected fast WC propulsion in a courtyard outside of the Seating Center at baseline and one-month post WC reconfiguration. Reaction forces applied by the hand to the pushrim during WC propulsion were measured using three strain gauge force transducers (240 Hz, SmartWheel). Upper extremity segment kinematics were captured in the frontal and sagittal planes (60 Hz) and using inertial measurement units (APDM). Push phase was defined from initial elbow extension to last contact with the pushrim. Within-participant comparisons were made using Cliff's step-down method.

RESULTS AND DISCUSSION

Elbow phase-plane patterns during push were maintained before and after WC reconfiguration (Figure 1). Half of the participants maintained torso extension (+) velocity pattern (Figure 1, P2), 8 maintained torso angle flexion (-) velocity pattern (Figure 1, P26), and 7 exhibited mixed results. Significant shifts toward the recommended elbow angle at push initiation [1] were observed in 13 of 30 individuals (Figure 2). Comparison of torso angular velocity at time of peak elbow extension velocity revealed significant differences in elbow-trunk coordination for six participants (Figure 2).

CONCLUSIONS

WC reconfiguration was found to be effective in shifting aspects of upper extremity and trunk control toward clinical guidelines [1] without introducing dramatic shifts in upper extremity control. Shifts in trunk control with WC reconfiguration at self-selected fast speeds in the community suggest personalized WC fitting can create improvements in posture while preserving stability.

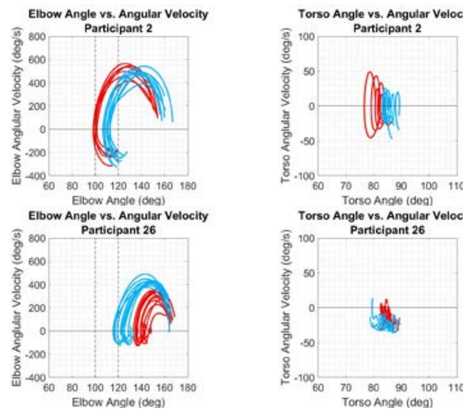

Figure 1. Exemplar kinematics for exemplar individuals during contact with pushrim. (Red: Baseline; Blue: 1-Month Follow-up)

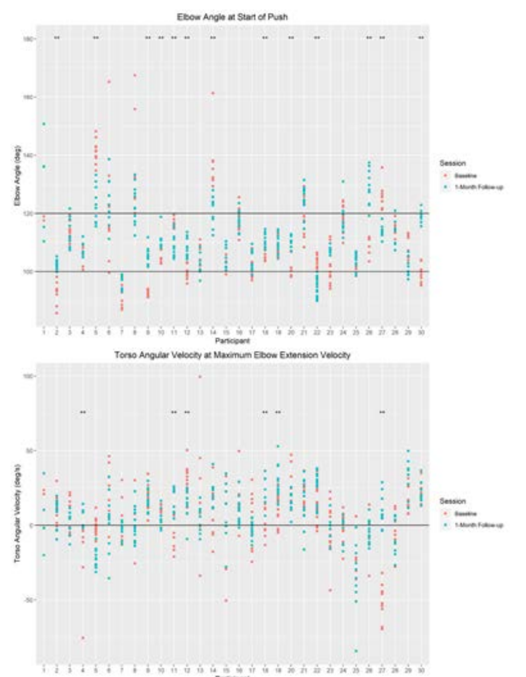

Figure 2: Comparison of elbow angle at initiation of push and torso angular velocity at peak elbow extension velocity before and after WC reconfiguration.

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TEMPORAL INVARIANCE IN SCA6 REFLECTS SMALLER CEREBELLAR LOBULE VI AND GREATER DISEASE SEVERITY

Basma Yacoubi, Agostina Casamento-Moran, David E. Vaillancourt, SH Subramony, Evangelos A. Christou

Presentation Preference: **Podium**

INTRODUCTION

Spinocerebellar ataxia type 6 (SCA6) is a slow progressing neurodegenerative disorder of the cerebellum[1]. There is abundant evidence that cerebellar atrophy, as occurring in SCA6, impairs temporal control[2]. Nonetheless, we have recently shown that some SCA6 patients exhibit greater temporal accuracy during fast goal-directed movements[3], presumably due to lower temporal variability. This lower temporal variability may be a consequence of a regional cerebellar change. Specifically, a recent study links reduced temporal variability and better motor performance to smaller cerebellar lobule VI[4]. Here, we test the hypothesis that SCA6 individuals with reduced temporal variability will exhibit distinct structural changes in cerebellar lobule VI and reduced disease severity.

METHODS

Nineteen SCA6 and 18 healthy controls performed fifty fast goal-directed contractions with ankle dorsiflexion aiming at a spatiotemporal target. We quantified the endpoint control of these contractions with force error and variability and temporal error and variability. We also quantified the gray matter integrity of the cerebellum (MRI), and disease severity using the International Cooperative Ataxia Rating Scale (ICARS).

RESULTS AND DISCUSSION

SCA6 individuals exhibited lower temporal endpoint error ($P<0.01$) and variability than the healthy controls ($P=0.01$). Statistically, SCA6 clustered into two distinct groups for temporal variability (Figure 1A). A group with low temporal variability ranging from 10-19% (SCA6a) and a group with temporal variability similar to healthy controls (SCA6b; 19-40%). In contrast to our hypothesis, SCA6a exhibited greater disease severity than SCA6b, as assessed with ICARS ($P<0.001$; Figure 1B).

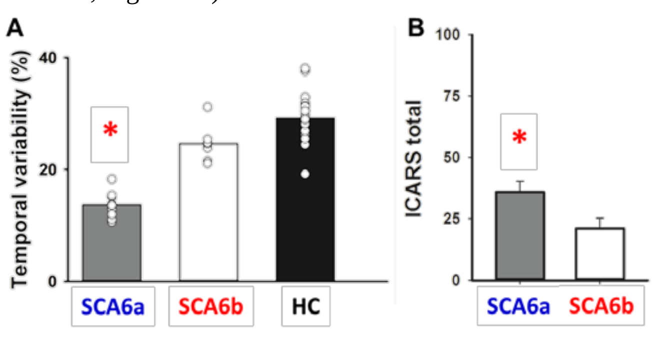

Figure 1: K-means cluster analysis clustered SCA6 into two groups, SCA6a with temporal variability below 19% and SCA6b with variability above 19% (A). Individuals in the SCA6b group clustered with healthy controls. Disease severity (ICARS total) was greater for the SCA6a than SCA6b (B). *=$p < 0.01$.

Lower temporal variability, which was independent of disease duration ($R^2=0.1$, $P>0.2$), correlated with greater ICARS ($R^2=0.3$) and was associated with lesser gray matter volume in cerebellar lobule VI ($R^2=0.35$; Figure 2A). SCA6a exhibited a smaller volume of cerebellar lobule VI than SCA6b (Figure 2B and C).

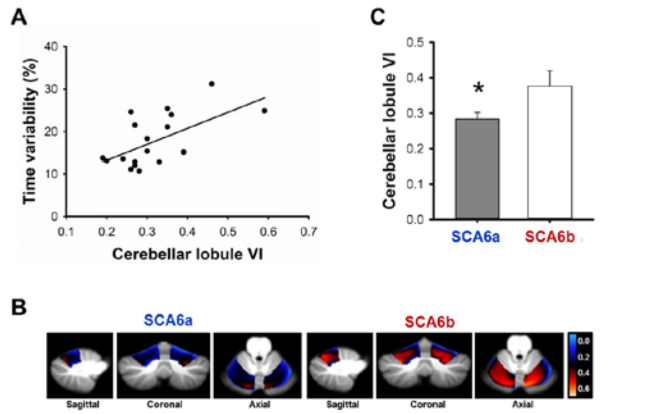

Figure 2: (A) Reduced time variability was predicted from lower grey matter volume in cerebellar lobule VI ($R^2=0.36$; $P=0.007$). (B) and (C) Grey matter volume in cerebellar lobule VI was smaller for SCA6a compared with SCA6b.* = $p < 0.05$.

CONCLUSIONS

For the first time in the SCA literature, we provide evidence that about half of the individuals with SCA6 appear to exhibit lower temporal variability than healthy controls during fast goal-directed contractions. However, in SCA6 this reduced temporal variability appears to be a signature for reduced grey matter volume of cerebellar lobule VI and greater disease severity. It remains unclear whether the temporally-invariant SCA6 forms a genetically distinct subtype of SCA6 that would possibly require alternative rehabilitation. In addition, our findings provide novel evidence relevant to theoretical motor control. We argue that pathological motor variability can manifest not only as an exacerbation but also as a reduction relative to healthy controls.

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CORRELATION BETWEEN INITIAL CLAUDICATION TIME, ABSOLUTE CLAUDICATION TIME, AND MUSCLE OXYGEN RECOVERY TIME

Henamari Ybay[1], Hafizur Rahman[1,2], Iraklis Pipinos[2,3], Jason Johanning[2,3], Sara Myers[1,2]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]Department of Surgery and VA Research Service, VA Nebraska-Western Iowa Health Care System, Omaha, NE USA
[3]Department of Surgery, University of Nebraska Medical Center, Omaha, NE USA
email: hybay@unomaha.edu

Presentation Preference: **Poster Only**

INTRODUCTION

Peripheral Artery Disease (PAD) is a cardiovascular disease caused by blockages of the leg arteries that reduce blood flow. Claudication, a cramping pain or tiredness in the ischemic legs, is the most prevalent symptom of PAD and impairs patient walking ability [1]. Oxygen delivery in the leg muscles is likely an important determinant of claudication and functional problems in these patients. The time of claudication pain onset and the time at which claudication pain forces the patients to stop walking are known as initial claudication time (ICT) and absolute claudication time (ACT) respectively. Previous studies have shown that health-related quality of life assessments are positively correlated with absolute claudication times [2, 3]. The purpose of this study was to identify if there is any relationship between claudication times and time to recovery of baseline muscle oxygen levels.

METHODS

Eleven male subjects with PAD (age: 68.91 ± 7.45 years, BMI: 32.59 ± 7.98 kg/m^2) were recruited through the clinics at the Nebraska-Western Iowa Veterans Affairs Medical Center. All subjects possessed an ankle brachial index < 0.90 as a precondition for PAD. The PortaMon (Artinis Medical System) is a muscle oxygen monitor that uses near infrared spectroscopy to measure the muscle oxygen saturation. This monitor was attached to the gastrocnemius muscle for all subjects. The subjects began the trial with a seated rest for 3 minutes to obtain a baseline. Then subjects performed a standardized graded treadmill test; a protocol speed of 0.89 m/s (2.0 mph) that began at 0% grade and increased 2% grade every two minutes. The subjects verbally reported the onset of claudication pain during the testing and the corresponding times were recorded as ICT. The subjects continued to walk until claudication pain forced to stop, which was recorded as ACT. The subjects were then placed into seated rest to monitor their muscle oxygen recovery. The recovery time was defined as the point at which muscle oxygen saturation levels reached a plateau. A Pearson's correlation was performed between the claudication times (ICT and ACT) and recovery time.

RESULTS AND DISCUSSION

There were no significant relationships between the claudication times and recovery time. The coefficient of determination was R^2=0.1526 for ICT and recovery time, and R^2=0.2371 for ACT and recovery time (Figure 1). Both sets of data provide little support that variability in recovery time is caused by variations in claudication times.

The current study includes only eleven patients and does not represent the entire PAD population. Including large number of patients will increase the statistical power of the study. Lack of correlation between claudication and recovery times indicate blood flow and oxygen delivery are not the only factors that determine how far patients with PAD can walk.

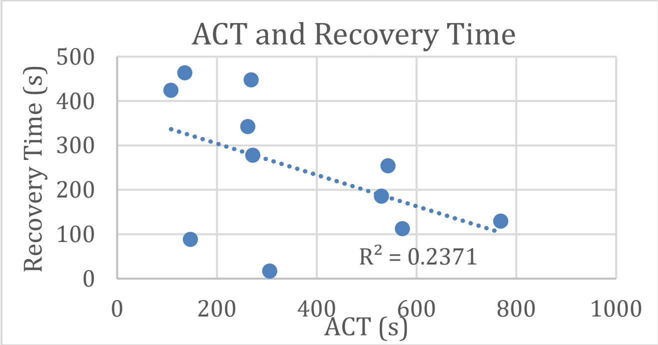

Figure 1: Scatter plot of absolute claudication time and recovery time. 23.71% of the variability in recovery time is explained by the absolute claudication time.

CONCLUSIONS

Our results suggest that there is no significant relationship exists between the claudication times and recovery time. Future studies should include more patients with several intervention methods to better understand their contributions in claudication distances, claudication times and recovery times in patients with PAD.

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EFFECT OF TREADMILL WALKING WITH HANDRAILS ON GAIT DYNAMICS IN PEOPLE WITH PARKINSON'S DISEASE

Lauren Yoksh[1], Ryan L. Meidinger[1], Daniel Jaravata[1], Danish Bhatti[2], & Vivien Marmelat[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[2]Department of Neurological Science, University of Nebraska Medical Center, Omaha, NE USA
email: sc2d.labuno@gmail.com

Presentation Preference: (3) **Poster**

INTRODUCTION

Human movement presents stride-to-stride variability [1-3]. The process of detrended fluctuation analysis (DFA) examines trends within the variability of movement and provides a scaling exponent, α. α-DFA values can provide significant insight on function and dysfunction of the locomotor system [4-5]. In healthy individuals, this α-DFA value represents an optimal state of gait. The gait complexity of people with Parkinson's disease (PD) represented by α-DFA values deviates towards randomness [1,4]. A possible explanation for the randomness of PD patients' movement is that the deviation from complex variability results from increased control mechanisms to avoid excessive postural instability [5-6]. The purpose of this study was to determine the effect of handrail use while walking on a treadmill on gait variability in patients with PD. Our central hypothesis was that walking while holding handrails will increase α-DFA in stride time and stride length, but decrease in stride speed, reflecting less randomness and better step-to-step locomotor control.

METHODS

Fifteen healthy young adults (HY), fifteen healthy elderly adults (HE), and fifteen patients with Parkinson's disease have been recruited to complete two fifteen-minute walking trials at a preferred walking speed on a treadmill.

Condition 1 involved the subject walking on the treadmill without any external assistance (no handrails). Condition 2 required the subject to hold onto the handrails of the treadmill while completing the walking trial (Figure 1).

Kinematics data were collected through the use of motion-capture cameras (at 120 Hz) that recorded reflective markers on the subject's anatomical landmarks.

The main outcomes are the variability (coefficient of variability, CV) and the complexity (DFA) of stride-to-stride fluctuations (stride time, stride length and stride speed), and the sacral marker deviations in the medial-lateral direction (reflecting overall body stability). A two-way ANOVA (3 groups x 2 conditions) will be used for comparisons. Pearson's coefficients of correlation will be used to determine the relationship between global body stability and stride-to-stride fluctuations.

RESULTS AND DISCUSSION

Data collections are still in progress. We present in Table 1 preliminary results from two patients with PD. The coefficient of variation (CV) tend to decrease for all spatiotemporal variables while holding handrails. The DFA results are also in line with our hypothesis, although one subject presented highly anti-persistent dynamics (low DFA) for stride speed, even without handrails. The CVs of sacral marker in the ML direction tend to reduce while holding handrails (from 1.60 and 1.38 to 1.03 and 0.69, for PD01 and PD02, respectively).

CONCLUSION

Walking on a treadmill while grasping handrails seems to increase the complexity of gait variability in patients with Parkinson's disease, which seems to be associated with reduced postural instability, reflecting the close relationship between gait complexity and motor stability.

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Table 1. Preliminary results from two patients with PD

		Stride Time		Stride Length		Stride Speed	
		No handrails	**Handrails**	**No handrails**	**Handrails**	**No handrails**	**Handrails**
CV	**PD01**	1.48	1.23	1.41	1.16	1.47	0.87
	PD02	1.83	1.84	1.95	1.82	1.47	1.21
DFA	**PD01**	0.76	0.95	0.78	0.97	0.19	0.18
	PD02	0.93	0.96	0.89	0.95	0.50	0.28