THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF KINESIOLOGY

# EFFECT OF FATIGUE OF ANKLE DORSIFLEXORS ON MUSCLE SYNERGIES DURING BODY SWAY

MOHAMMED BASITH
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in Biology
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Reviewed and approved* by the following:

Mark Latash
Distinguished Professor of Kinesiology
Thesis Supervisor

Stephen Piazza
Associate Professor of Kinesiology
Honors Adviser

* Signatures are on file in the Schreyer Honors College.

**ABSTRACT**

The main purpose of this experiment was to test the effect of fatigue of the ankle dorsiflexors (primarily the tibialis anterior muscle group) on multi-muscle synergies during voluntary sway. The hypothesis posed was that fatigue would lead to changes in the M-mode compositions and that fatigue would lead to higher variance in the elemental variables (M-modes), but that this variance would not affect the performance variable (COP stabilization). Confirming this hypothesis would mean that multi-muscle synergies were used to organize muscles during voluntary sway under fatigue conditions. Subjects performed a series of 12 voluntary sway trials, first without fatigue trials. Subjects then performed a second set of 12 voluntary sway trials with a two minute fatigue trial between each two voluntary sway trial. Data concerning center-of-pressure stabilization and electromyography activation (for twelve muscle groups) was collected. Analysis of the data led to the conclusion that there was a clear difference between muscle activation, M-mode compositions, and variance in the M-modes pre-fatigue and post-fatigue. Increases in activation and variance were seen in many of the muscle groups studied. This variance did not significantly affect the performance variable, though with much of the post-fatigue variance being attributed to $V_{UCM}$, or variance not affecting the performance variable. There was a significant amount of "bad" variance measured by $V_{ORT}$, though, which suggests that the synergy between the muscles may not have been 100% efficient in maintaining performance variable performance.

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## INTRODUCTION

Motor control is the study of how the central nervous system interacts with the rest of the body and the environment to produce meaningful movements. The idea that highly specific tasks can be performed accurately through coordination of the two systems listed above is a major point of research. This accuracy in task performance brings about the question of motor redundancy. Motor redundancy is the notion reflecting the fact that in most actions, at any level of description, the number of elements is larger than the number of constraints resulting in an infinite number of possible ways for an individual to perform a task, including activation of different neuronal pathways and different muscle groups (Bernstein, 1935, 1967; Turvey, 1990). Because it is generally accepted that the CNS controls large groups of muscles by sending signals to several muscles simultaneously (not one signal per muscle) resulting in parallel scaling of their activation levels, there must be a way to decrease the number of variables that control movement.

How is it possible to study the problem of specific movement production if there is an infinite number of solutions? One answer is the idea that muscles work in groups called synergies to produce specific outputs. This idea of synergies has been put into research practice on several organisms, including chick embryos, spinal frogs, cats, and humans (Bradley and Bekoff, 1990; Holdefer and Miller, 2002; Johnston and Bekoff, 1996; Lemay and Grill, 2004; Saltiel et al., 2001).

One method researchers can use to understand these synergies is by implementing matrix factorization to group muscles based on their activation (Saltiel et al., 2001; Krishnamoorthy et al., 2003a, b, 2004; d'Avella et al., 2003; Ivanenko et al., 2005, 2006; Ting and Macpherson, 2005; Torres-Oviedo et al., 2006; Torres-Oviedo and Ting, 2007). These grouped muscles are

called muscle modes (M-modes). When one muscle in an M-mode experiences a change in activation, the other muscles analyzed in that M-mode often experience similar changes in activation, an example of co-activation and synergical action between muscles in that M-mode (Ivanenko et al., 2004; Ting and Macpherson, 2005; Tresch et al., 2006).

There is evidence that increases in activation of specific muscles modes can lead to recruitment of other muscle modes when a specific task must be performed. This idea of multi-muscle-mode synergies brings up the questions, what specific muscle groups work in such synergies and what effect do those synergies have on movement? In this context, the word "synergy" means co-varied involvement of elements (muscle groups) that stabilize an important characteristic of performance. One effect of multi-muscle-mode synergies is that they have been shown to stabilize a person's center of pressure (COP, "the point of application of the resultant vertical force acting on the body from the support", Krishnamoorthy et al., 2003b, 2004; Wang et al., 2005**)**. Having control over one's COP is necessary for purposes of simply remaining in a standing position. During voluntary sway, it is possible to study stability of the COP during movement shifts. There is evidence that higher rates of change of performance variables can have an effect on coordinated involvement of elements (Latash et al.,2002b; Goodman et al., 2005; Shim et al., 2005**)**. The importance of multi-muscle-mode synergies is therefore paramount in the study of motor control because without stability of motor performance is its vital feature for everyday movements.

Within the last fifteen years, a new framework has been organized with which to study multi-muscle-mode synergies. This framework is based on the uncontrolled manifold (UCM) hypothesis. The UCM hypothesis considers two requirements for organization of muscles. These requirements are that muscles provide stability as well as flexibility. According to the

UCM hypothesis, the CNS acts in a space of elemental variables and organizes in that space two sub-spaces, one that corresponds to a fixed, desired value of a performance variable (UCM), and the other within which that variable changes. This fits well with the idea of multi-muscle-mode synergies because of the COP stabilization properties of multi-muscle-mode synergies as well as the flexibility allowed for completing tasks.

In general terms, UCM hypothesis allows for a study of the efficiency of system by testing variability in specific elemental variables when compared to stability of a performance variable (Scholz and Schoner, 1999; reviewed in Latash et al., 2002a, Latash, 2008). For research in motor control, these elemental variables are the M-modes and the performance variable is the COP. If there is a large amount of variation in the M-modes that affects stability of the COP, that variation is considered "bad variation", labeled $V_{ORT}$. This term is used because "bad variation" is orthogonal to "good variation", labeled $V_{UCM}$. If $V_{UCM}$ is significantly greater than $V_{ORT}$, a synergy between the elemental variables can be assumed (Scholz and Schoner, 1999).

Fatigue is known to lead to a drop in muscle force and accuracy of force production. In multi-element systems, however, accuracy of important performance variables may be shielded from effects of fatigue of a subset of elements (Singh et al., 2010). This results from making most variance in the space of elemental variables "good". Such effects have been so far seen only in multi-finger studies after fatigue of a finger. In this specific experiment, the purpose was to test the effect of fatigue of the ankle dorsiflexors (primarily the tibialis anterior muscle group) on multi-muscle synergies during voluntary sway. The hypothesis posed was that fatigue would lead to changes in the M-mode compositions and that fatigue would lead to higher variance in the elemental variables (M-modes), but that this variance would not affect the performance

variable (COP stabilization) much because most of it is going to represent “good variance”. Confirming this hypothesis would mean that multi-muscle synergies were strengthened during voluntary sway under fatigue conditions.

## METHODS

### Subjects

Eleven subjects (7 males and 4 females) with the mean age 22.2 years (±3.4 SD), mean weight 67.9 kg (±10.1 SD) and mean height 175.1 cm (±9.9 SD) participated in the experiment. All subjects were healthy, without any known neurological or muscular disorder and all subjects were self-reported as right-limb dominant. All subjects gave their written informed consent based on the procedures approved by the Office for Research Protection of The Pennsylvania State University.

### Apparatus

The horizontal and vertical components of the reaction force in the anterior–posterior and direction ($F_x$ and $F_y$) and the moment of force around the frontal axis (My) was recorded using a force platform (AMTI). A goniometer (Biometric Inc, UK) was used to record the angle of ankle dorsiflexion. A Myopac 16-Channel EMG System and disposable self-adhesive electrodes (3M™ Red-Dot™) were used to record the surface muscle activity (EMG) of the following muscles of the right leg and trunk: gastrocnemius lateralis (GL), gastrocnemius medialis (GM), soleus (SOL), tibialis anterior (TA), biceps femoris (BF), semitendinosus (ST), rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), tensor fasciae latae (TFL), lumbar erector spinae (ES), and rectus abdominis (RA). The electrodes were placed over the muscle bellies on the right side of the subject's body. The distance between the two electrodes of each pair was 3 cm. The signals from the electrodes were pre-amplified (5000x). All signals were sampled at 1,000 Hz with a 12-bit resolution. A desktop computer (Dell 2.40 GHz) was used to control the experiment and to collect the data using customized Labview-based software (Labview 8.2— National Instruments, Austin, TX, USA).

Procedures

First, subjects were instructed to stand on a force plate with their feet in parallel at hip width (the inside of the feet 15 cm apart). This foot position was reproduced across all trials. At the start of the experiment, two control trials were performed that were used in the data processing for normalization of the EMG signals. A detailed description of the procedure is given in Danna-dos-Santos et al. (2007). In summary, subjects were standing quietly and holding a 5 kg load in front of their body with their arms fully extended for 10 s. The subjects held the load by holding the circular panels at each side of a handle bar (See Figure 1).

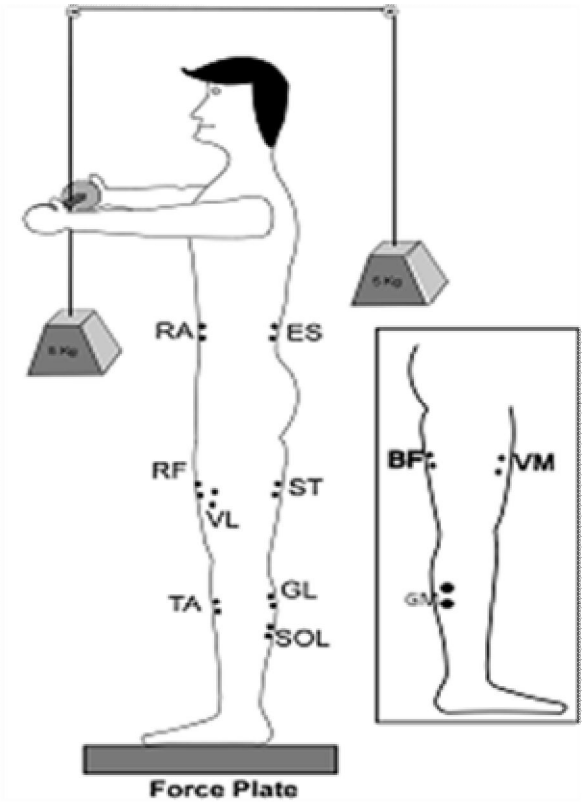



**Figure 1:** Represents the subject's posture during the control trials. The load was hung on the front for the first control trial and on the back for the second control trial. Some of the EMG electrode positions are also labeled. Figure from: Danna-dos-Santos, et al. (2007).

For the first trial, the load was suspended from the middle of the bar producing a downward force. For the second trial, the load was attached through a pulley system such that it produced upward acting force on the bar. In a third control trial, the subject was asked to sway as far forward and backward as possible, without falling. This was used to determine the maximum amplitude of swaying. The target amplitude of sway for the main task was set at 60% of the maximum amplitude when swaying backwards (Klous, 2010).

After the control trials and prior to data collection, a period of familiarization with the task was given to each subject. During the familiarization period, subjects performed voluntary sway at frequencies of 0.25, 0.5, and 0.75 Hz to the beat of a metronome. For all sway trials in this study, subjects were presented with anterior-posterior moment of force feedback on a computer screen (see Figure 2). Two 30 s practice trials were completed at each frequency.

Once subjects felt comfortable swaying at the three different frequencies, data was collected. The main task was split into two parts. The first part involved continuous voluntary sway in the anterior–posterior direction in three sets of four 30 s trials (12 trials total). The sway for each set of trials was to the beat of a metronome at frequencies of 0.25, 0.5, and 0.75 Hz. The order of sway trials at each frequency was randomized between subjects

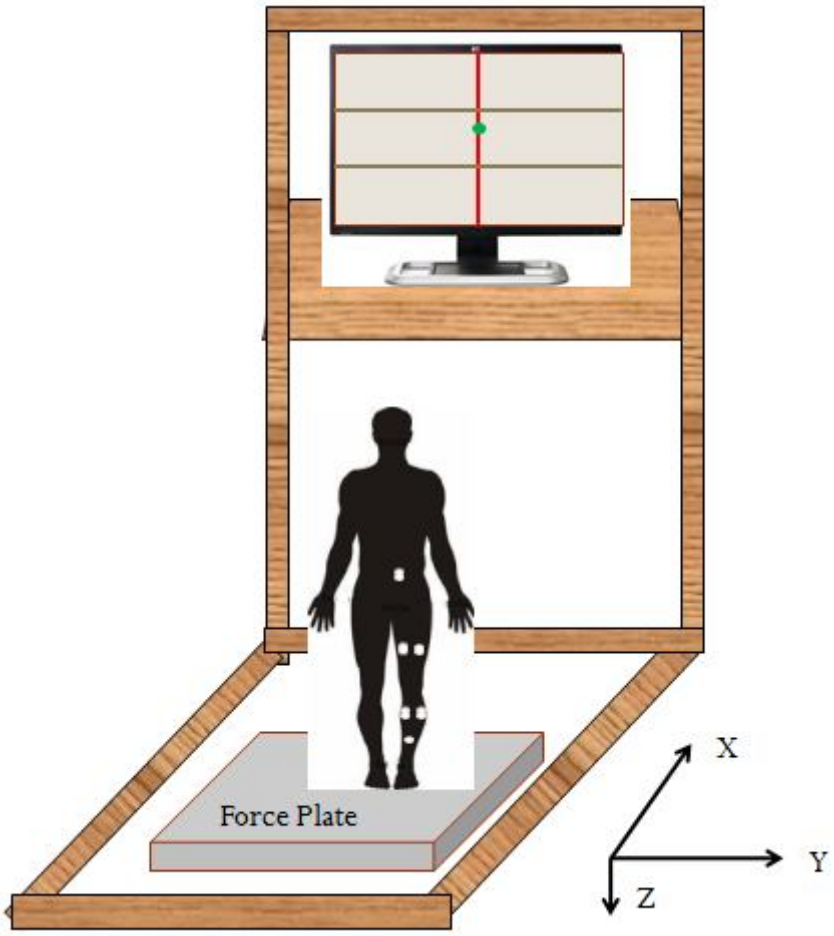



**Figure 2:** Represents the subject's posture during the sway trials. The computer screen provides feedback on moment of force along the x axis (anterior-posterior).

The second part of the study involved alternating trials of fatigue and sway trials. During the fatigue trials, a load of 8% (±1.84 SD) of the subject's body weight was attached to a subject's ankle via a pulley system such that, when the ankle was dorsiflexed, a downward force was produced (see Figure 2). This setup was designed to fatigue only the tibialis anterior (TA) muscle group. Cushioning was placed between the subject's foot and the pulley system apparatus to avoid pain due to the apparatus. A goniometer was attached to the medial side of the ankle to measure the angle of ankle flexion. The subject was instructed to maintain an angle

of 20°. Fatigue trials lasted for two minutes. After the first fatigue trial, subjects stepped onto the force plate and performed EMG control trials as were conducted in the first two trials of this experiment.

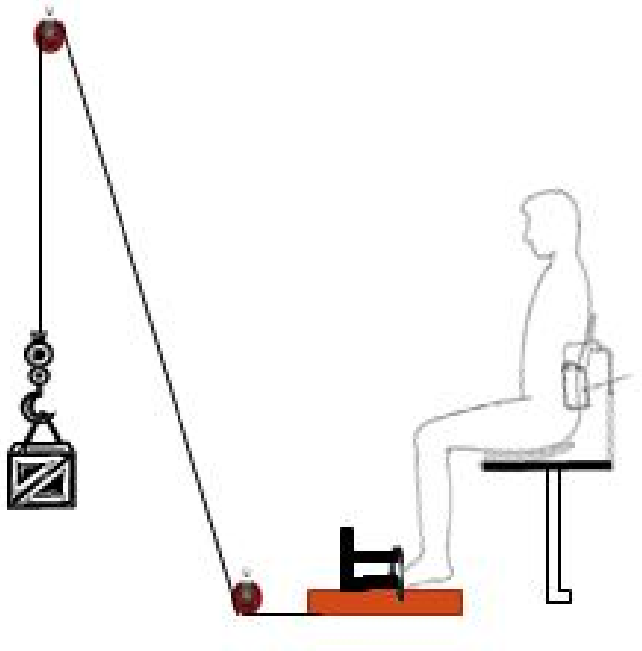
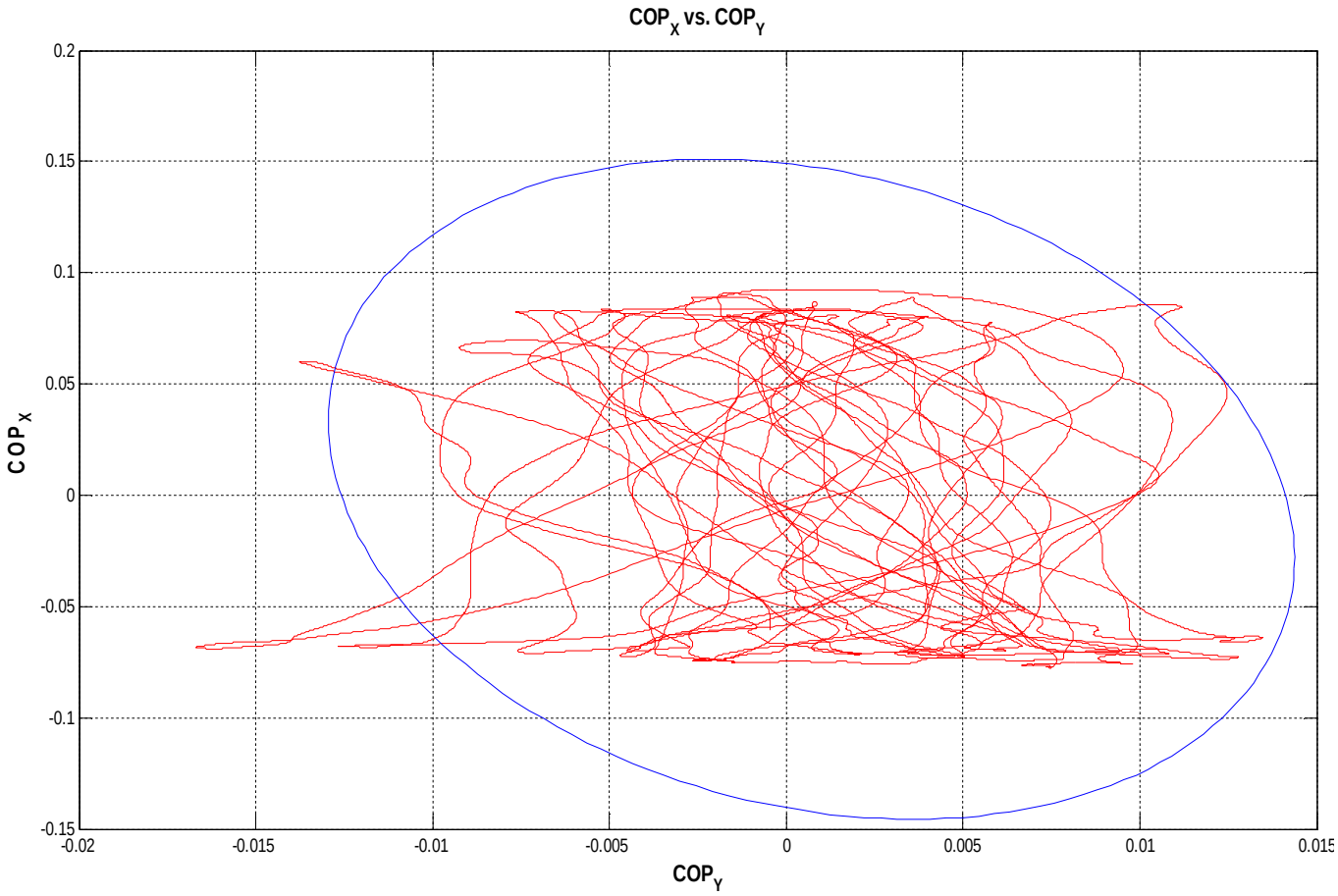


**Figure 2:** Represents the subject's posture during the fatigue trials.

Next, subjects performed alternating trials of one fatigue trial followed by two sway trials (with same sway parameters as in the first part of the experiment). Sway trials were at one of three frequencies (0.25, 0.5, and 0.75 Hz). During this part of the experiment, a total of six fatigue trials and twelve sway trials were run (four trials at each frequency). Three sets of two fatigue trials and four sway trials were run for each frequency. The order of sway trials at each frequency was randomized between subjects. Subjects were given unlimited time to rest after each set of two sway trials and before the next fatigue trial. On average subjects rested for one minute after each set of sway trials.

**RESULTS**

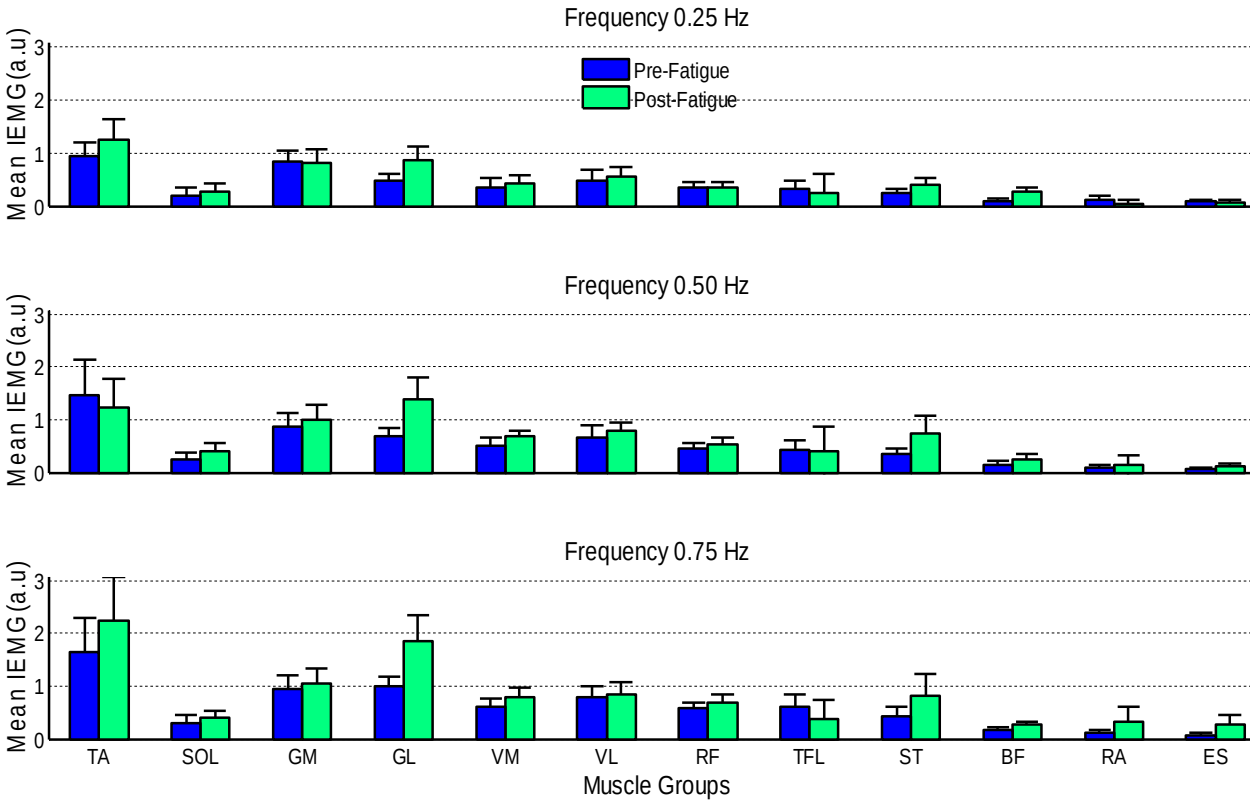
Figure 1: Mean COPx and COP y During Sway




This figure shows COPx vs. COPy. The blue ellipse is a 95% confidence interval. The figure is meant as a measure of accuracy for voluntary sway.

There were three main categories of data plotted for analysis. The first was regarding the performance variable, COP during voluntary sway (see figures 1 and 3). The second involved EMG activation and EMG variance (see figures 2, 6, and 7). The third involved good and bad variance, labeled $V_{UCM}$ and $V_{ORT}$, respectively (see figures 4 and 5).

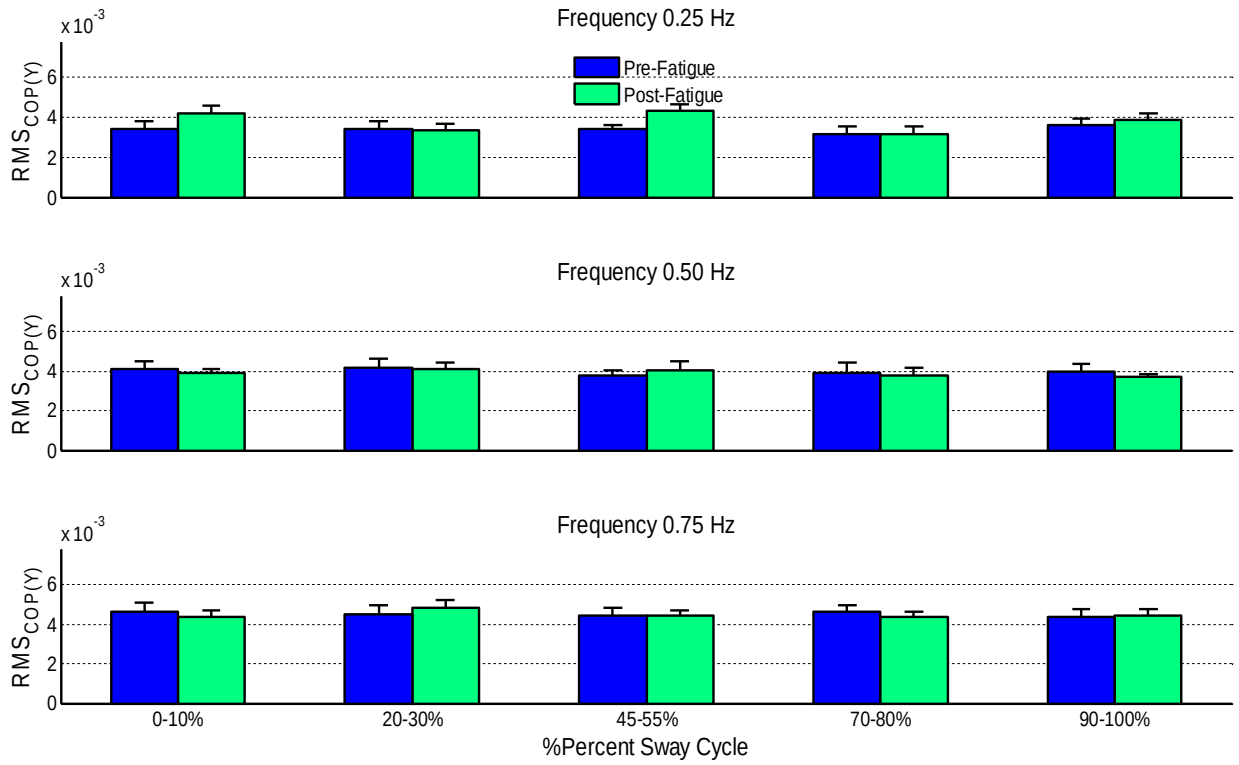
Figure 2: Mean EMG Activation Values for 12 Muscle Groups Studied




This figure shows mean EMG activation values for the 12 muscle groups studied. Data was collected using Myopac 16-Channel EMG System.

The general trend seen in figure 2 is toward an increase in muscle activation post-fatigue compared to pre-fatigue.

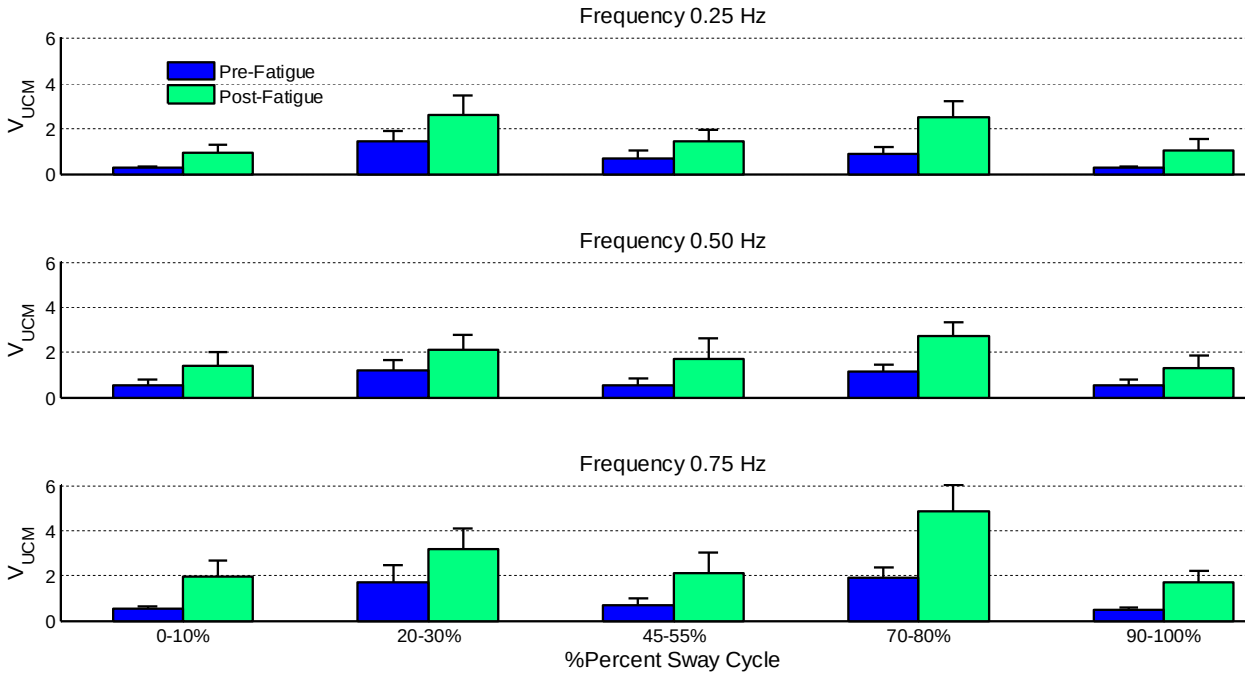
Figure 3: RMS COPy (Anterior-Posterior Direction) Values




This figure shows the RMS values for COPy at the three different frequencies of sway. It is meant as a measure of accuracy for voluntary sway.

A trend seen in Figure 3 is that the post-fatigue RMS COPy values were very similar to pre-fatigue values, suggesting that there was minimal effect of fatigue on the performance variable.

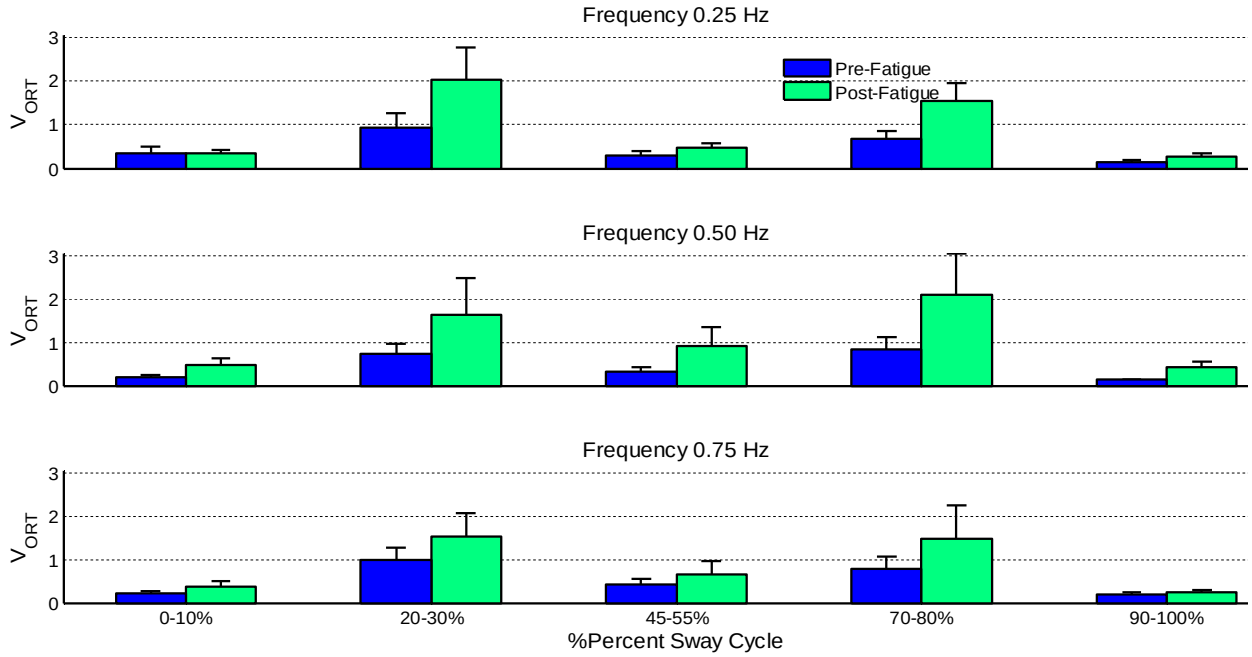
Figure 4: $V_{UCM}$ Values




This figure shows the relative $V_{UCM}$ values for the three different frequencies of sway. It is meant as a measure of "good" variance of the performance variable, COP.

A trend seen in Figure 4 is that the "good" variance after fatigue is significantly greater after fatigue than before fatigue during all intervals of the sway cycle.

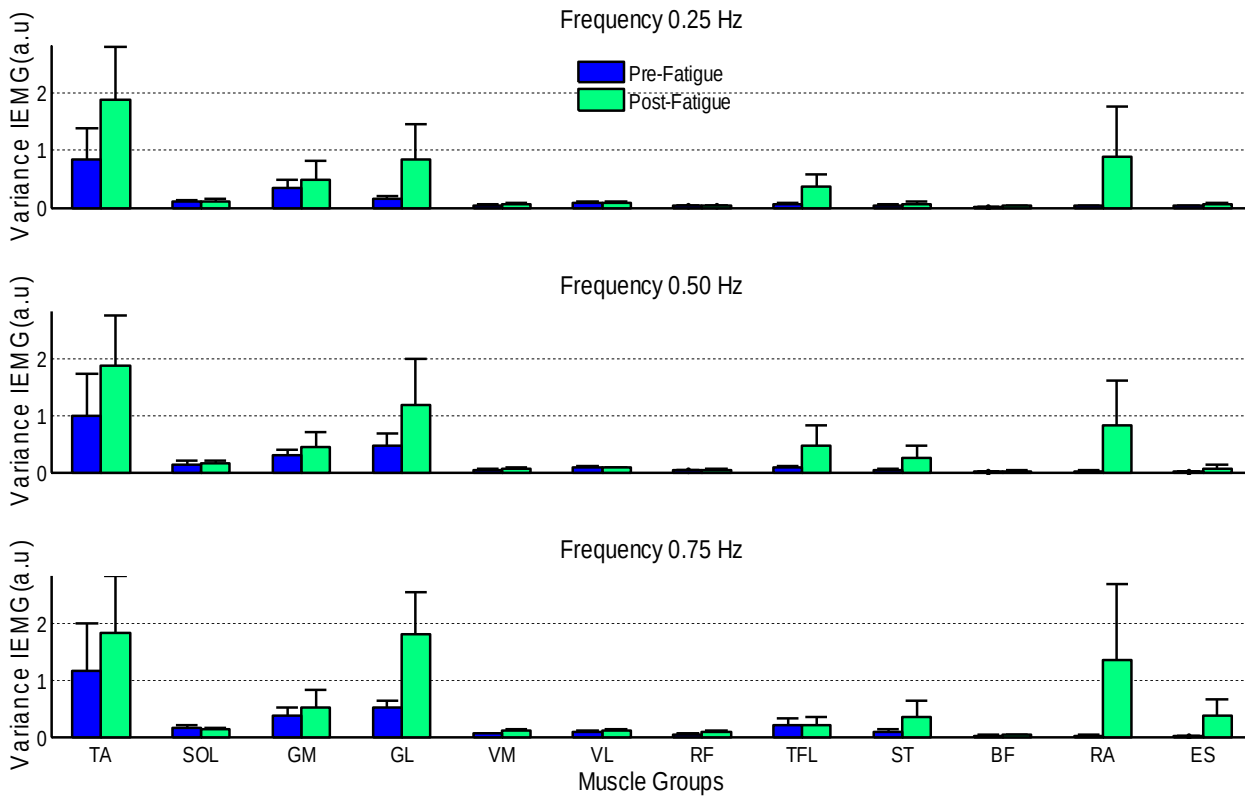
Figure 5: $V_{ORT}$ Values




This figure shows the relative $V_{ORT}$ values for the three different frequencies of sway. It is meant as a measure of "bad" variance of the performance variable, COP.

A trend seen in Figure 5 is that the "bad" variance after fatigue is significantly greater after fatigue than before fatigue during many of the intervals of the sway cycle.

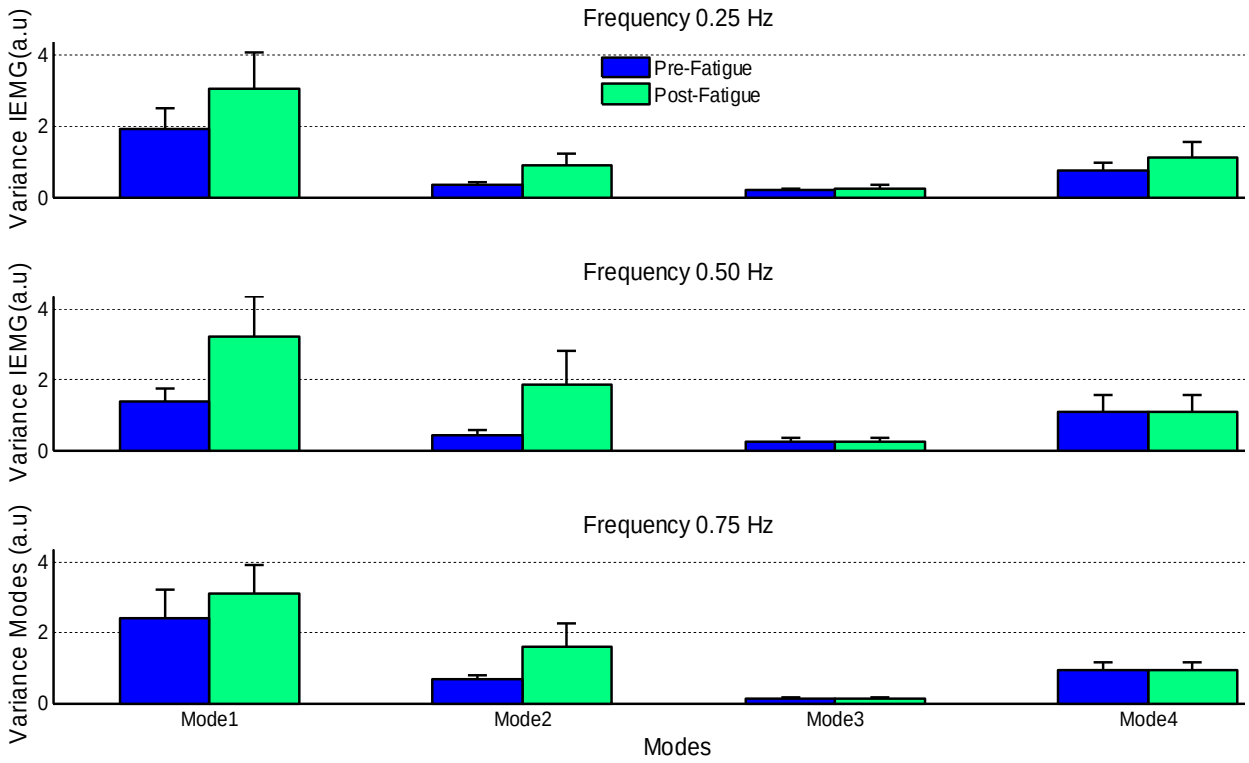
Figure 6: Variance in EMG for the 12 Muscle Groups Studied




This figure shows the variance in EMG activity of the 12 muscle groups studied. The data was recorded during voluntary sway at three different frequencies. It is meant as a measure of muscle activation.

A trend seen in Figure 6 is that the variance in the EMG after fatigue is significantly greater after fatigue than before fatigue in many of the muscle groups studied. Some muscle groups that specifically have higher post-fatigue variances are the tibialis anterior, gastrocnemius lateralis, semitendinosus, and rectus abdominis.

Figure 7: Variance in EMG for the Four Muscle Modes (Sorted Based on Activation)




This figure shows the variance in EMG activity of four muscle modes. The four modes were determined based on the activation in EMG shown in Figure 2 above. The data was recorded during voluntary sway at three different frequencies. It is meant as a measure of muscle activation.

A trend seen in Figure 7 is that, after grouping the muscle groups into muscle modes, the variance in the EMG after fatigue is significantly greater after fatigue than before fatigue in M-modes 1 and 2. The variance of the tibialis anterior activation level is included in the variance of M-mode 1.

## DISCUSSION

There were three main groups of data analyzed in this study. The first was a measure of the performance variable, COP shifts in voluntary sway, the second involved EMG activation and variance, and the third involved $V_{UCM}$ and $V_{ORT}$. These were all measured in conjunction with fatigue trials to test the effects of fatigue of the ankle dorsiflexors on synergies involved in voluntary sway.

When analyzing the performance of the subjects on the voluntary sway trials, it is necessary to analyze the COP in the x (medial-lateral) and y (anterior-posterior) planes. Because of the incredible ability of the human body to stabilize COP, there should only be a shift on the order of millimeters. This can be seen in Figure 1 (drawn with a 95% confidence interval to demonstrate the level of variability in COP). Based on this figure, the medio-lateral shift was very limited. Another figure that provides information on COP is Figure 3. Figure 3 demonstrates pre- and post-fatigue RMS values for shift in the COPy. There was not a significant difference in the pre- and post-fatigue values of COPy, demonstrating that subjects were equally capable of performing the voluntary sway before and after the fatigue trials. This is slightly surprising because it was obvious while running the experiment that the subjects all demonstrated physical fatigue. Based on the results, though, this fatigue did not seriously affect the COP stabilization during voluntary sway. This provides evidence to confirm the original hypothesis that the fatigue would not affect the performance variable.

The next step after seeing whether the performance variable was affected is to test how the elemental variables, muscles in muscle modes, were affected. Before running the study, it was hypothesized that muscles would co-activate leading to synergies between muscle groups, termed multi-muscle-mode synergies. Based on Figure 2, there seemed to be a general trend in

most muscles toward an increase in activation post-fatigue compared to pre-fatigue. This trend was especially obvious in the tibialis anterior, gastrocnemius lateralis, semitendinosus, and biceps femoris. This trend of increased activation reflects two phenomena. The first is the increase in the EMG of a fatigued muscle to produce a required force. The second is less trivial: Muscles that were not fatigued also showed an increase in their activation. This may be seen as a sign of adaptation within the CNS.

Based on these differences in activation, there will likely be variance in the EMG results. This variance is plotted in figures 6 and 7. Figure 6 displays variance in specific muscles and features a trend of increasing variances from pre-fatigue to post-fatigue. This trend was especially observed in the tibialis anterior (TA), gastrocnemius lateralis (GL), semitendinosus (ST), and rectus abdominis (RA). Variance in the TA, GL, and ST was expected because of the differences in activation seen in Figure 2 due to the well-known phenomenon of signal-dependent noise. The variance in the RA could demonstrate co-activation between other muscles involved in sway and the RA.

Next, the muscles were grouped into four M-modes with variances plotted in Figure 7. The muscles group including the tibialis anterior was designated as M-mode 1, which demonstrated a significantly higher variance post-fatigue when compared to variance pre-fatigue. A similar increase in variance was seen in M-mode 2, while the last two muscle modes showed fairly constant variance when comparing pre-fatigue variance to post-fatigue variance. This higher variance in M-mode 2 that did not involve fatigued muscles reflected compensation for the effects of fatigue.

The final step of analysis is to test whether this variance was caused by “good” variance (variance not affecting the performance variable) or “bad” variance (variance affecting the

performance variable). Because results seen in Figures 1 and 3 demonstrate that subjects were fairly competent in performing voluntary sway before and after fatigue, it could be assumed that variance affecting the performance variable would be minimal. This good variance, $V_{UCM}$, is plotted in Figure 4 as a function of the percent of each sway cycle that has passed. Comparing $V_{UCM}$ pre-fatigue and post-fatigue, there is a clear increase in the variance that does not affect the performance variable. This makes sense because of the inherent variability that fatiguing a muscle can cause. This also suggests that there was a synergy between the muscles because this increased variance did not affect the performance variable. Figure 5 demonstrates the bad variance, $V_{ORT}$, as a function of the percent of the sway cycle that has passed. Compared to the "good" variance, a similar increase in $V_{ORT}$ post-fatigue was seen. This increase in $V_{ORT}$ may demonstrate that the efficiency of the synergy between muscles was compromised. In a less difficult task with less fatigue to the muscle, though, this affect of "bad" variance might be limited. Statistical analysis has shown that the fatigue induced increase in $V_{UCM}$ was larger than in $V_{ORT}$, which may be interpreted as an increase in the strength of a multi-M-mode synergy stabilizing COP coordinate after fatigue.

The main conclusion that can be made from this data analysis is that the hypothesis posed was verified by the data. This hypothesis was that fatigue would lead to changes in the M-mode compositions and that fatigue would lead to higher variance in the elemental variables (M-modes), but that this variance would not affect the performance variable (COP stabilization). There was a clear difference between muscle activation, M-mode compositions, and variance in the M-modes pre-fatigue and post-fatigue. Increases in activation and variance were seen in many of the muscle groups studied. This variance did not significantly affect the performance variable, though with much of the post-fatigue variance being attributed to $V_{UCM}$, or variance not

affecting the performance variable. There was a significant amount of "bad" variance measured by $V_{ORT}$, though, which suggests that the synergy between the muscles may not have been 100% efficient in maintaining performance variable performance.

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## APPENDIX

Sample Subject Consent Form

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The Pennsylvania State University
Institutional Review Board
Office for Research Protections
Approval Date: 05/25/2010 – J. Mathieu
Expiration Date: 05/24/2011 – J. Mathieu

**Informed Consent Form for Biomedical Research**
The Pennsylvania State University

**Title of Project:** The Effect of Fatigue on Motor Synergies

**Principal Investigator:** Dr. Mark Latash, Rec.Hall-267, Department of Kinesiology, University Park, PA 16802; tel: (814) 863-5374; e-mail: mll11@psu.edu

**Co-Investigators:** Tarkeshwar Singh, Miriam Klous, Varadhan Kariyamaanikam, Vladimir Zatsiorsky

1. **Purpose of the research:** The purpose of this research is to understand how human beings control voluntary movements involved in prehension, postural control and locomotion tasks when a group of muscles or a group of digits involved in these tasks have been fatigued. The muscles involved in postural and locomotion tasks are are quadriceps, hamstrings, soleus, tibialis anterior, tibialis posterior and gastrocnemius. The digits are the thumb, the index, the middle, the ring, and the little finger. By performing this research, we hope to improve our present understanding of control variables that are used by the brain for movement control.

2. **Procedures to be followed:** If you agree to take part in this research, you will be asked to perform certain simple motor tasks including standing, marching-in-place, and perform body sways. Reflective sensors may be placed on your body to record the movements. Disposable, self-adhesive electrodes may be placed over some of the muscles of the leg and trunk to record muscle activity. A fatiguing protocol will follow the pre-test. The fatiguing protocol could be a simple exercise like squating till you feel tired enough to not be able to continue in the squating position. You will not be asked to lift any loads while squatting. An alternative fatiguing protocol could be to do leg-press, leg-curl or leg-extension movements in order to fatigue specific group of muscles. After the fatiguing protocol, you will perform the same simple motor tasks that you had performed during the pre-test. Sufficient rest will be provided between a set of pre and post trials that have a fatiguing protocol in between. Before the next trial(s), you will be orally asked if you are comfortable to resume the experiment and only when you affirm that you are good to go, would the next trial be done.Reflective sensors may be placed on your body to record the movements. Disposable, self-adhesive electrodes may be placed over some of the muscles of the leg and trunk to record muscle activity.For each experimental study, the data will be pooled with the data of about 10-12 other participants to draw conclusions.

3. **Discomforts and risks:** There is no risk in any of the procedures different from that in the everyday life. The system used to record body movements uses cameras and passive, reflective markers; the system to record muscle activity uses approved electromyographic equipment with secure isolation from the power supply.

4. **Benefits:** There are no benefits to you. The benefits to society include better understanding of the neural mechanisms of control of voluntary movements.

5. **Duration/time of the procedures and study:** Your participation in the research will take one to three visits to the Laboratory; each visit will last about two hours. The first visit may be scheduled now; the second visit (if necessary) may be scheduled at a later time (during the next 2 weeks).

6. **Statement of confidentiality**: Your participation in this research is confidential. Your data will be coded and only the persons directly involved in the project will have access to the codes. All your data will eventually be deleted from all the computers that it has been stored on after ten years. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared. The following may review records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services; The U.S. Food and Drug Administration (FDA) if applicable; The Penn State University Institutional Review Board (IRB); The Penn State University Office for Research Protections.

7. **Right to ask questions**: You can ask questions about this research. Contact Dr. Mark Latash at 814-863-5374 with questions or concerns or if you feel this study has harmed you. Please contact the Office for Research Protections (ORP) at (814) 865-1775 with questions, complaints or concerns about your rights as a research participant, if you feel this study has harmed you, or if you would like to offer input. The ORP cannot answer questions about research procedures. All questions about research procedures can be answered by the research team.

8. **Payment for Participation**: In return for your participation, you will be paid at a rate of $25 per visit. We would pay participants at each visit, for up to three visits for a total of $75.

9. **Voluntary participation**: Participation is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

10. **Injury Clause**: In the unlikely event you become injured as a result of your participation in this study, medical care is available but neither financial compensation nor free medical treatment is provided. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

You must be 18 years of age or older to take part in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

You will be given a copy of this signed and dated consent for your records.

_____ _____

Participant Signature Date

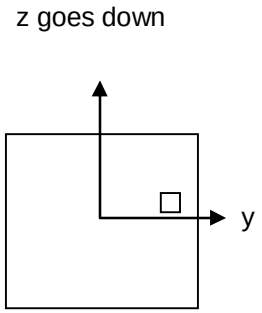
_____ _____

Person Obtaining Consent Date

Sample Protocol Form

Date:
Subject:
Age:
Height:
Weight:
Dominant Leg:

**Muscles**
tibialis anterior:Channel 1 (16)
soleus:Channel 2 (17)
gastrocnemius medialis:Channel 3 (18)
gastrocnemius lateralis:Channel 4 (19)
vastus medialis:Channel 5 (20)
vastus lateralis:Channel 6 (21)
rectus femoris:Channel 7 (22)
tensor fasciae lataeChannel 8 (23)
semitendinosus:Channel 9 (32)
biceps femoris: Channel 10 (33)
rectus abdominis:Channel 11 (34)
erector spinae:Channel 12 (35)




***Control trials***

| | Condition | Trial | Task | Comments |
|---|---|---|---|---|
| 0-measurement | | | Determine offset force plate 1 | 2 sec. |
| Quiet stance | | | Determine body weight | 2 sec, hold your breath |
| Calibration EMG | 4 | 1 | Holding load in front | 10 sec. |
| | 4 | 2 | Holding load in the back | 10 sec. |
| | 4 | 3 | No Load | 10 sec |
| Standardize body sway | Open another Program | | Determine max. body sway → back to 60% of CoP | 30 sec. |
| Check EMG | | | Ankle, knee and hip flexion,extension | Not fixed |
| | | | | |

***Actual trials***

| Condition | Frequency (Hz) | Trial | comments |
|---|---|---|---|
| 1 | **1.0** | 1 | 30 seconds |
| 1 | **1.0** | 2 | 30 seconds |
| *1* | ***1.0*** | *3* | *30 seconds* |
| *1* | ***1.0*** | *4* | *30 seconds* |
| 1 | 3.0 | 1 | 30 seconds, |
| 1 | 3.0 | 2 | 30 seconds |
| *1* | *3.0* | *3* | *30 seconds* |
| *1* | *3.0* | *4* | *30 seconds* |
| 1 | **2.0** | 1 | 30 seconds, |
| 1 | **2.0** | 2 | 30 seconds |
| *1* | ***2.0*** | *3* | *30 seconds* |
| *1* | ***2.0*** | *4* | *30 seconds* |

| | | | |
|---|---|---|---|
| 3 | 4 | 1 | 2 minutes |

| | | | | |
|---|---|---|---|---|
| Calibration EMG | 4 | 4 | Holding load in front | 10 sec. |
| | 4 | 5 | Holding load in the back | 10 sec. |
| | 4 | 6 | No Load | 10 sec |

| | | | |
|---|---|---|---|
| 3 | 1.0 | 1 | 2 minutes |
| **Offset COP** | | | |
| **2** | **1.0** | **1** | **30 seconds** |
| **2** | **1.0** | **2** | **30 seconds** |
| 3 | 1.0 | 2 | 2 minutes |
| **Offset COP** | | | |
| ***2*** | ***1.0*** | ***3*** | ***30 seconds*** |
| ***2*** | ***1.0*** | ***4*** | ***30 seconds*** |
| 3 | 3.0 | 1 | 2 minutes |
| **Offset COP** | | | |
| **2** | 3.0 | **1** | **30 seconds** |
| **2** | 3.0 | **2** | **30 seconds** |
| 3 | 3.0 | 2 | 2 minutes |
| **Offset COP** | | | |
| ***2*** | *3.0* | ***3*** | ***30 seconds*** |
| ***2*** | *3.0* | ***4*** | ***30 seconds*** |
| 3 | 2.0 | 1 | 2 minutes |
| **Offset COP** | | | |
| **2** | **2.0** | **1** | **30 seconds** |
| **2** | **2.0** | **2** | **30 seconds** |
| 3 | 2.0 | 2 | 2 minutes |
| **Offset COP** | | | |
| ***2*** | ***2.0*** | ***3*** | ***30 seconds*** |
| ***2*** | ***2.0*** | ***4*** | ***30 seconds*** |

# ACADEMIC VITA of Mohammed A. Basith

Mohammed A. Basith
309 East Beaver Ave, Apt 402
State College, PA, 16801
mbasith812@gmail.com

Education: Bachelor of Science Degree in Biology, Penn State University, Spring 2011
Honors in Kinesiology
Thesis Title: Effect of Fatigue of Ankle Dorsiflexors on Muscle Synergies During Body Sway
Thesis Supervisor: Dr. Mark Latash

Work/Volunteer Experience:

**Teaching Assistant at Pennylvania State University**
- Summer 2009-Present in University Park, PA
- Teaching undergraduate level biology lab courses covering topics including Human Physiology, Comparative Anatomy, Genetics, and Botany

**Volunteer at Williamsport Hospital and Medical Center**
- Summer 2002-Present in Williamsport, PA
- Assisting nurses and physicians on nursing floors and in the emergency room
- Over 250 hours of service

**Shadowing at Williamsport Hospital and Medical Center**
- Summer 2003-Present in Williamsport, PA
- Observing nurses, surgeons, and other physicians during daily work
- Included exposure to: Pediatrics, Family Medicine, Emergency Medicine, Cardiology, Orthopedic Surgery, Neurosurgery, Gastrointestinal Surgery, and Anesthesiology

**Tennis Instructor at Penn State Tennis Camp**
- Summer 2009 in University Park, PA
- Helping high school students learn to play tennis

Activities:
- President of Penn State Tennis Club: 2009-Present
- Active Member of Penn State Tennis Club: 2007-Present
- Active Member in PSU Dance Marathon Fundraising Activities (Organization raised over $7 Million for Four Diamonds Fund Pediatric Cancer Charity in 2008, 2009, and 2010)