IMMEDIATE EFFECTS OF MUSCULAR FATIGUE ON POSTURAL STABILITY 
AND MOTONEURON POOL EXCITABILITY IN HEALTHY ADULTS

by

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Approved:

Department Honors Advisor

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ABSTRACT

BACKGROUND: The dynamic effect that fatigue plays on acute neuromuscular excitability has been studied at length without arriving at either an accepted explanation or adequate understanding. Researchers agree that the mode by which fatigue is achieved may contribute to the body's response and recovery. Eccentric exercise, as a method by which fatigue is achieved, is commonly incorporated due to its qualities of producing a high muscle strain and low energy expenditure simultaneously. The influence of eccentric-induced fatigue, as it pertains to postural stability and motoneuron pool excitability, is not well understood. PURPOSE: The aim of this study is to investigate the impact of fatigue on motoneuron pool excitability and postural stability in healthy adults. HYPOTHESIS: Motoneuron pool excitability will be facilitated despite a simultaneous inhibition in postural stability. METHODS: Twelve volunteers (24.4 ± 6.7 yrs; female n=6; male n=6) participated in a single 10-minute bout of eccentric exercise-induced fatigue. H-reflex measurements, used to measure motor pool excitability, and a Limits of Stability (LOS) test, used to quantify postural stability, were administered prior to and immediately following exercise participation. T-tests were utilized to compare eccentric fatigue's effect on the specific neural functions previously delineated. RESULTS: Statistical significance (t11=+2.408, p=0.035) was found on one measure of postural stability, in which there was a facilitation. CONCLUSION: Implications for such findings indicate that eccentric-induced fatigue may more actively be prescribed as part of an appropriate rehabilitation and physical therapy protocol without exposing clients to a risk for increased neuromuscular compromise. Such findings are intended to serve as
preparation for extending the investigation to an elderly cohort who may benefit more
directly from the integration of eccentric exercise within therapeutic protocols.
To my sweetheart, Cinthia, who has supported me in all of my varied academic pursuits.
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INTRODUCTION

As early as the fourth century B.C. E., the nature and complexity of the nervous system was being debated. Aristotle, himself, took up the quest, postulating that all nerves originated from the central organ, which in his mind was the heart. However, long after Aristotle's demise, Galen, a Roman physician from the second century C.E. contradicted those long held beliefs with the idea that the central organ was the brain and that all nerves emanated from it. Surprisingly, it was not until just after the twelfth century C.E., that Master Nicolaus replaced the terms "hard" and "soft" with "motor" and "sensory", respectively, in attempting to describe different types or functions of various nerves. Long has the nervous system been studied. Many are the questions left unanswered.

When individuals speak about the human nervous system, more specificity should be used, for there are multiple divisions that perform unique tasks. An overview, in brief, should discuss both the central and peripheral aspects of the nervous system. The central nervous system (CNS) is comprised of the brain and the spinal cord. An analogy that lends itself to conceptualizing their relationship would be the role of a president and vice president, respectively. The CNS plays a large role in integrating the various pieces of information communicated to it regarding the external environment, both inside and outside of the body. The peripheral nervous system (PNS) is the term describing the aggregate of nerves outside of the brain and spinal cord. These nerves are the highways that communicate the information back to the integrating centers. To carry on the business analogy, it is rare to have a president that is aware of the working of the company without the reports of a staff of VPs, the same is true regarding the relationship
between the PNS and CNS. The two main types of highways used by the PNS are called afferent and efferent neurons. The highways within the CNS are called interneurons.

As mentioned, the nervous system is comprised of three types of neurons: afferent, efferent and interneurons. The afferent neurons are those responsible for communicating a condition or stimulus back to an appropriate location, typically found in the spinal cord or brain. Efferent (motor) neurons are the avenues through which the chosen response is carried out. For example, an efferent neuron will carry the signal to pull your hand back from a fire. The interneurons are utilized for communication between levels of the CNS (i.e. within the spinal cord and brain). The nervous system is complex, but its complexities do not mean that insight cannot be gained by measuring its normal functioning capability and comparing that with its functionality while in a compromised state.

Although much of the complexity of the nervous system eludes our comprehension, one concept that has been elucidated quite fully is the reality of various reflexes and their clinical application to assessing neural health and integrity. Sir Charles Sherrington was a pioneer of the late 19th and early 20th centuries in which the discovery and study of reflexes was in full sway. Ultimately, his work afforded the receipt of a Nobel Prize, but his conceptualization of the nervous system has allowed many scientists since to investigate and discover a litany of reflexes. One such reflex is termed the Hoffmann Reflex (H-reflex), abbreviated for its discoverer, Paul Hoffmann (Hoffmann, 1910). Hoffmann's purpose was to use the H-reflex to study many of the internal and external factors on nerve signal propagation. His initial questions have led to years of research and discovery into the intricacies of the nervous system.
The H-reflex is a multi-faceted tool that can be used to extrapolate the integrity of the neural system. Research has shown that the H-reflex is one of the more preferred assessment tools, due to its ability to circumvent the muscle spindle, thereby permitting the investigator to examine the modulation of monosynaptic reflex activity in the spinal cord (Schieppati, 1987). In other words, the H-reflex affords the researcher the ability to almost isolate external effects on the neural system, thereby exclusively studying synaptic inhibition and facilitation. Historically, the H-reflex has been utilized in its ability to assess neural conditions (Fisher, 1992; Braddom & Johnson, 1974), pain (Leroux, Belanger, & Boucher, 1995), musculoskeletal injuries (Palmieri, Ingersoll & Hoffman, 2004; Hopkins & Palmieri, 2004) and the effect of various therapeutic protocols. (Krause, Hopkins, Ingersoll, Cordova, Edwards, 2000; Oksa, Rintamaki, Rissanen, Rytky, Tolonen, Komi, 2000; Wynne, Burns, Eland, Conatser, Howell, 2006) Essentially, the H-reflex is a tool that is utilized in order to measure synaptic transmission efficiency. (Capaday, 1997) The H-reflex is seen by the majority of researchers as the amount of one’s muscle potential that is being recruited. This relative amount is derived from the absolute motoneuron pool potential, as determined by the maximum wave resulting from direct electrical stimulation of the respective nerve. (Pierrot-Deseilligny, & Mazevet, 2000) The latter is referred to as the M-wave.

The H-reflex can also be used to qualitatively extrapolate spinal cord integrity and afferent/efferent communication. This approach is logical in its theory, but in order for the assessments to be able to infer neural adaptations or compromise, baseline data must be established prior to a compounding incident, such as an injury. There has not been enough data collected to even attempt to establish any “normal” ranges of H-reflex/M-
wave ratios. Absolute values would not be useful when attempting to use the H-reflex as a diagnostic tool due to the variation between individuals and the changing physiological state within an individual. The theories surrounding how an H-reflex will be affected by dynamic changes are largely debated. Several researchers have put forward the notion that following an adequate fatigue bout, motor pool excitability will be inhibited. (Armstrong, 2006; Trimble & Harp, 1998) However, various researchers have likewise posited that the specific type of fatigue protocol will largely impact the effect of such perturbations. (Alderton & Moritz, 1996; Yaggie & Armstrong, 2004) There is no unanimous view of the best use of the H-reflex.

In addition to using H-reflex assessments to examine neural integrity, an individual’s postural stability should also be investigated in order to obtain a general conception of nervous system functionality. Postural stability is the unconscious muscular control of one’s static or dynamic posture. Various healthcare professionals have attempted to use one’s postural stability as an immediate diagnostic tool for sports related injuries and various orthopedic problems (Wilkins, Valovich-McLeod, Perrin, Gansneder, 2004).

The literature is not in agreement regarding the role of fatigue on postural stability or fall risk. While muscular fatigue adversely effects postural stability during athletic tasks (Wilkins, Valovich-McLeod, Perrin, Gansneder, 2004), fatigue’s impact on the fall risk of an aging individual has not been well established. Many studies have found that static postural stability is negatively affected by muscle fatigue in addition to eliciting changes in motor unit behavior (Derave, Tombeaux, Cottyn and colleagues, 2002; Gandevia, 2001; Hashibe, 1998; Johnston III, Howard, Cawley and colleagues, 1998; Krogh-Lund, 1993; Nardone, Tarantola, Girodano and colleagues, 1997; Maton & Gamet, 1989). While one study claimed that there was no effect on postural stability due to muscular fatigue (Strang & Berg,
2007), others showed a significant, albeit temporary, effect following generalized fatigue (Ledin, Fransson, & Magnusson, 2004; Nardone, Tarantola, Giordano, Schieppati, 1997; Bove, Faelli, Tacchino, Lofrano, Cogo, Ruggeri, 2007). Neither the impact of fatigue on postural stability nor the potential mechanisms by which changes may occur have been adequately discussed. Despite the lack of literature to explain the immediate fatiguing effects on neurophysiology, several researchers have posited that an anticipatory postural adjustment (APA) may reduce the impact that fatigue has on the body during various dynamic perturbations (Vuillerme, Nougier, & Teasdale, 2002; Allison & Henry, 2002; Strang & Berg, 2007). These responses have often been seen to precede voluntary upper limb movement as a means of stabilizing the body during motion (Vuillerme, Nougier, & Teasdale, 2002; Allison & Henry, 2002; Bonnetblanc, Martin, & Teasdale, 2004; Aruin & Latash, 1995a; Aruin & Latash, 1995b; Zattara, & Bouisset, 1988). Despite similar findings, the researchers differed in their hypotheses regarding the role of the CNS in such regulations.

Both the H-reflex and postural stability of an individual are useful in examining injured or aging populations, provided that the subjects are investigated in a compromised physiological state. The reasoning follows that in order to understand the effects of primary aging or the impact of a high intensity exercise bout, the neural indicators must be studied within multiple environments. Since fatigue is an example of an altered physiological state, despite the difficulty to quantify its presence, I have selected it as the environment in which the current investigation will proceed. I will define fatigue as an exercise of at least 10 minutes in duration requiring a maximum volitional resistance throughout. The difficulty with precisely identifying an adequate fatigue state has led at least one researcher to supplant accuracy with ambiguity regarding fatigue. The aforementioned limitations results in less applicability of the researcher's findings (Garrandes, Colson, Pensini and colleagues,
2007). It is crucial to note that the way by which fatigue is induced may also affect the results of the research. From being equated with depressed cortical excitation to depleted cellular enzymes, fatigue is not easily defined or subsequently quantified. (Gandevia, 2001)

Having already been established, fatigue can be induced in a variety of methods, with different underlying mechanisms responsible - Eccentric muscular contraction being one such method. For common understanding, let us define eccentric exercises as those muscular contractions that resist any given external force. The fitness industry often refers to such an exercise as a "negative". Eccentric exercise protocols are seen as controversial due to traditional beliefs that they induce damage to the muscle and/or tendon rather than supporting hypertrophy. (LaStayo, Woolf, Lewek, Snyder-Mackler, Reich, Lindstedt, 2003) Sarcopenia, the progressive loss of skeletal muscle is presenting public health concerns for the aging population. Many therapists and physicians are attempting to study the impact of resistance training on muscle mass decline (Evans, 1995; Hortobagy, Tunnel, Moody, Beam, DeVita, 2001). Two appealing aspects that draw researchers and the physically active individual towards eccentric training is that, in comparison to the traditional concentric resistance training, greater forces can be exerted, while a lower metabolic cost is required. (Bigland-Ritchie & Woods, 1976) Although this type of resistance training is often studied in younger cohorts, at least one study has shown that the elderly cohort, suffering from the effects of sarcopenia also experience muscle mass increases following eccentric resistance training (LaStayo, Ewy, Pierotti, Johns, Lindstedt, 2003). The previous study also found a significant decrease in fall risk following eccentric exercise.

Due to the increasing number of health professionals using the H-reflex and postural stability measures to indicate neural compromises, the integrity of such findings
must be examined further. As the use of an eccentric exercise protocol increases, a more complete understanding of its immediate and long-term effects must be conceptualized. Therefore, the purpose of this study is to investigate the immediate effects of fatigue on both the H-reflex and postural stability. The findings from this study, which will examine a healthy, young cohort, will later be used to guide the study of an elderly population. The results may additionally be applied to the young demographic being originally studied.

METHODS

Subjects

Twelve volunteers (6 males, 6 females; age=24.4 ± 6.7 yrs, height=169.98 ± 8.39 cm, mass=74.56 ± 19.82 kg), with no self-reported neural/cognitive compromise and no history of surgery/injury to the lower extremity within the previous twelve months participated in this study. Each subject was instructed to continue their normal activities of daily living with the exception of any fatiguing exercise and ingestion of food or caffeine within 1 hour prior to research participation. Subjects were also instructed to refrain from strenuous exercise for a 24-hour period immediately prior to testing research participation. Testing for each subject consisted of one two-hour session. Subjects provided informed consent and the study was approved by the University of Utah Institutional Review Board (IRB).

Procedures

Subject and Instrument Set-up

Surface electromyography (MP100, BIOPAC Systems Inc., Santa Barbara, California, USA) was used to measure the H-reflex and M-wave. After shaving,
abrading, and wiping the skin with isopropyl alcohol, pre-gelled, self-adhesive disposable vinyl Ag-AgCl recording electrodes (1 3/8-inch) were placed over the soleus muscle belly and lateral malleolus of the ipsilateral leg.

An electrical stimulator (S88, Grass Instruments Inc.) was used to elicit spinal reflex responses. To stimulate the soleus, an unshielded 12 mm stimulating electrode was applied to the skin over the tibial nerve, in the popliteal fossa. In order to verify that the electrode was placed correctly, the electrode was moved over the tibial nerve until a proper neural response registered on the recording equipment. Once the tibial nerve was successfully located, it was secured with the use of adhesive tape and the neural response was verified again to ensure that adhesive application did not interfere with the neural response. An outline with pen was made in order to be consistent with electrode placement during the post-fatigue measurement. A dispersal pad, serving the purpose of an anode, was placed on the distal thigh above the knee. A constant current unit (CCU1, Grass Instruments Inc., W. Warwick, RI, USA) and a stimulus isolation unit (SIU5, Grass Instruments Inc.) were used in order to limit the risk of unforeseen injury secondary to electrical malfunction of the equipment.

Postural balance and stability was examined with the use of a Limits of Stability (LOS) protocol and Neurocom balance plate (Neurocom International, Inc., Clackamas, OR, USA). Subjects were required to align and maintain foot position based on a predetermined height equation. Subjects were then instructed to follow visual cues to move in specific directions, by leaning their trunk appropriately, while keeping their feet planted on the balance plate. Results for both initial (Endpoint Excursion - EPE) and overall movement (Maximum Excursion - MXE) accuracy were compiled and electronic
representations were produced for statistical examination. The Center of Gravity was the relative position being tracked during the LOS protocol. The LOS protocol evaluated 8 specific movements, beginning first straight forward and moving clockwise with each subsequent trial until the final trial is forward-left. A familiarization with the balance testing apparatus was implemented prior to initial data collection in order to delimit the possible interaction of a learning curve within the analysis of our findings. During this period each subject performed the LOS evaluation twice, and was then instructed that the third trial was the beginning of our actual data collection.

Following initial data collection, subjects performed a fatigue bout utilizing eccentric exercises of the lower legs. Subjects were seated as according to Figure 2 on the Eccentron (Eccentron, LLC, Denver, CO, USA). Resistance levels were subjectively applied by the participant, rather than pre-set for all subjects. A graphical representation of current exertion level was produced which guided the verbal encouragement of the investigators. The fatigue protocol consisted of one 10-minute bout of exercise. The pedals of the apparatus are designed to move towards the seated participant who is charged with resisting the movement, while remaining in a seated position. Should the participant rise from the seat, a mechanical fail-safe would engage and terminate the pedal movement, in order to prevent hyperextension. Additionally, participants were seated at a distance from the pedals in order to ensure that at least 10-15° of flexion was constant.
Subject Positioning

Subjects were tested in the prone position (Figure 2) with the left ankle positioned and maintained at 90° of dorsiflexion. A body pillow was used to standardize body, head, and hand position for each subject.
Measurement

To capture peak-to-peak amplitude of the H-reflex and M-waves, EMG measurements were collected at a rate of 1 sample per 10-15 seconds, totaling 15-20 samples. AcqKnowledge waveform acquisition software for Microsoft Windows (AcqKnowledge Software v.3.7.3, 1992-2002, Biopac Systems, Inc. Goleta, California, USA) was used to determine the peak-to-peak amplitude of the H-reflex and M-wave recruitment curves.

Examination of the EPE and MXE were conducted according to a series of algorithms incorporated within the Neurocom program and LOS protocol. The basis of the measurements focused on the deviation of the COG.

The above measurements were performed both prior to and following the proscribed fatigue bout. Following the fatigue protocol, the LOS evaluation was performed immediately, followed by H-Reflex and M-wave measurements.

Statistical Analysis

Paired t-tests (comparing pre-fatigue vs. post-fatigue values) were used to examine H-reflex and M-wave data. Additionally, paired t-tests were also utilized to represent and effect that fatigue may have had on the subject's postural stability as indicated by their EPE and MXE. The level of significance for both sets of analysis was set to $\alpha < 0.05$.

RESULTS

Significance ($t_{11}=+2.408, p=0.035$) was found by utilizing a paired t-test evaluating EPE for the third position. While not statistically significant ($t_{11}=+2.043, p=0.066$), the eighth
EPE measure of the LOS showed trends towards facilitation. A lack of significance on all other factors was observed. For complete results, see table 1.

<table>
<thead>
<tr>
<th>Paired Samples Test</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Std. Error</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 1 EPE_1pre - EPE_1pos</td>
<td>6.66667 34.31759 9.90663</td>
<td>-15.13769 28.47102</td>
<td>.673 11</td>
<td>.515</td>
</tr>
<tr>
<td>Pair 2 EPE_2pre - EPE_2pos</td>
<td>1.83333 19.02550 5.49219</td>
<td>-10.25489 13.92156</td>
<td>.334 11</td>
<td>.745</td>
</tr>
<tr>
<td>Pair 5 EPE_5pre - EPE_5pos</td>
<td>-.75000 19.04122 5.49673</td>
<td>-12.84822 11.34822</td>
<td>-.136 11</td>
<td>.894</td>
</tr>
<tr>
<td>Pair 7 EPE_7pre - EPE_7pos</td>
<td>-1.50000 11.75894 3.39451</td>
<td>-8.97128 5.97128</td>
<td>-.442 11</td>
<td>.667</td>
</tr>
<tr>
<td>Pair 8 EPE_8pre - EPE_8pos</td>
<td>5.83333 9.88878 2.85464</td>
<td>-.44969 12.11636</td>
<td>2.043 11</td>
<td>.066</td>
</tr>
</tbody>
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Table 1.

While no statistical significance was found in MXE (Table 2), similar trends to those of EPE were seen, with near significance reported on the eighth movement of the LOS protocol.

<table>
<thead>
<tr>
<th>Paired Samples Test</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
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<tr>
<td>Mean</td>
<td>Std. Error</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pair 1 MXE_1pre - MXE_1</td>
<td>2.50000 9.29609 2.68413</td>
<td>-3.40773 8.40773</td>
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<td>.372</td>
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<tr>
<td>Pair 2 MXE_2pre - MXE_2</td>
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<td>-1.28028 9.94695</td>
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<tr>
<td>Pair 3 MXE_3pre - MXE_3</td>
<td>3.16667 7.00433 2.02198</td>
<td>-1.28378 7.61700</td>
<td>1.566 11</td>
<td>.146</td>
</tr>
<tr>
<td>Pair 4 MXE_4pre - MXE_4</td>
<td>3.08333 13.35840 3.85624</td>
<td>-5.40419 11.57086</td>
<td>.800 11</td>
<td>.441</td>
</tr>
<tr>
<td>Pair 5 MXE_5pre - MXE_5</td>
<td>4.16667 19.37587 5.59333</td>
<td>16.47751 8.14417</td>
<td>-.745 11</td>
<td>.472</td>
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<td>Pair 6 MXE_6pre - MXE_6</td>
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<td>.144</td>
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<td>Pair 7 MXE_7pre - MXE_7</td>
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<td>-.08797 8.92131</td>
<td>2.158 11</td>
<td>.054</td>
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</table>

Table 2.

No significance was seen when comparing measurements performed prior to and following the fatigue session, as seen in Table 3.
DISCUSSION

Within the context of research, it is commonly unacceptable to not yield statistically significant findings. However, in the present investigation, the absence of such results indicates a potentially misunderstood physiological response to a fatigue protocol. In other words, widespread assumptions tend to support the idea that fatigue will temporarily compromise the neuromuscular mechanisms used for balance and the motor pool availability itself. On the contrary, our results found that no such position was statistically supported, but rather that an acute facilitation is observed immediately following fatigue. In attempting to explicate objective reasoning for the lack of finding evidence for neuromuscular inhibition, several possibilities may provide a structure for future research and current understanding.

The first area of consideration is the tool utilized to evoke a sufficient amount of neuromuscular fatigue. Our study implemented an eccentric activity, in opposition to the common use of concentric fatigue protocols. Multiple researchers have also found that the type of exercise used in order to produce neuromuscular fatigue results in unique fatigue profiles. (Kay, Gibson, Mitchell, Lambert, Noakes, 2000; Enoka & Stuart, 1992; Armstrong, Grinnell, Cole, Van Gilder, 2006) Future studies may bear out that the way by which fatigue is achieved may alter the way by which the body responds and repairs.
Additionally, while the vast majority of research reports a clear inhibition of the H-reflex following a fatigue bout, the lack of widespread significance for either inhibition or facilitation in our current study of eccentrically-induced fatigue requires explanation. If further inquiry reveals that, in fact, the type of exercise bout determines the body's response, then it is quite feasible that this response would be neurally observed and may therefore produce facilitating or inhibiting neural effects, as measured by the H-reflex. Task-specific depression of the Soleus H-reflex, due to various levels and types of motor training, has been reported (Gruber, Taube, Gollhofer, Beck, Amtage, Schubert, 2007; Taube, Gruber, Beck, Faist, Gollhofer, Schubert, 2007; Perez, Lungholt, & Nielsen, 2005). Such findings support the increasing potential for compounding the influence of the nature of the eccentric exercise on neuromuscular fatigue itself, due to the fitness level of the subject themselves. Yet, if the motor training of the subject considered within the scope of the above-cited investigations did not include participants with a high level of motor training, then the findings of our study may have been underestimated and may therefore reveal more facilitated effects than that which we have currently found. Reasoning behind the observed facilitation is largely theoretical and needs extensive research to solidify any suppositions. One possible justification for the findings is that when the body has been taxed to the point of fatigue, the neuromuscular system engages specific mechanisms that serve to protect the body. Much like the oft-cited "flight or flight" response, when the body senses the potential danger that fatigue can induce, the neuromuscular system becomes hypersensitive to various stimuli which allows a greater response than normal to an equivalent stimulus. However, such a possibility begs the question as to why many researchers observe an acute inhibition attributing the
occurrence to neuromuscular compromise. Again, we refer back to the findings and conjectures of multiples researchers who note that the means by which fatigue is achieved affects the way by which such fatigue is revealed. In other words, if there are multiple ways by which fatigue can be induced, then the corollary that multiple neuromuscular reactions should exist, is the logical conclusion.

Another explanation to account for our findings involves the methodology of the protocol itself, in which subjects refrained from strenuous exercise for a period of 24 hours prior to examination. Research has been conducted that has incorporated similar guidelines in a fatigue-inducing protocol (Garrandes, Colson, Pensini and colleagues, 2007). Due to the period of rest from strenuous exercise, the fatigue protocol may not have been adequate to result in a large amount of muscular fatigue. Irrespective of the reality of fatigue being present, while the specific structure of the methods may have eliminated certain variables which could influence fatigue limits, the imposed restraints on the subject also pushed the findings of the research further from reality and application. For example, few individuals know when an injury will result and would be able to benefit from such a foreknowledge by avoiding exercise for 24 hours prior to the anticipated incident. A possible remedy to the above dichotomy would be to allow subjects to continue their daily habits prior to research participation and then compare the controlled and uncontrolled subject groups.

Paradoxically, most researchers have found that postural stability is likewise compromised following a fatigue bout (Alderton, & Moritz, 1996; Lundin, Fuerbach, & Grabiner, 1993; Ochsendorf, Mattacola, & Arnold, 2000), yet our investigation revealed a statistically significant facilitation of postural stability in one out of eight
measurements. Such a finding is difficult to explicate, though some possibilities include
the safety mechanism of the body which was described above, as well as a delayed
learning curve in the use of the LOS apparatus itself. However, the latter reason is
unlikely due to the familiarization period that was allotted to each participant prior to data
collection. Despite the plethora of inhibitory findings, research has shown that a decrease
in postural stability does not always follow a fatiguing exercise protocol. (Derave, De
Clercq, Bouckaert, Pannier, 1998) Even among the researchers who have reported a
balance compromise following fatigue, several have noted that pre-exercise balance
levels are regained within 20 minutes following the completion of the fatigue protocol
(Derave, De Clercq, Bouckaert, Pannier, 1998; Nardone, Tarantola, Giordano,
Schieppati, 1997; Nardone, Tarantola, Galante, Schieppati, 1998; Yaggie, McGregor &
Armstrong, 1999; Westcott, Crowe, Deitz, Richardson, 1994), thereby indicating that the
effect of fatigue seems to only effect the first 10-20 minutes following exercise. If
negative risks are associated with fatiguing exercises, then participants should be
encouraged to rest for 20-30 minutes before engaging in the remainder of their daily
activities.

It has often been discussed that the tool used to measure a given variable is the
cause for the discrepancy in research findings. Therefore, many investigators find fault
with simple paired t-test evaluations in which the subject has volitional control by citing
that a learning curve often accounts for the improvement in a subject’s results. In
accordance with similar research, a familiarization with the balance testing apparatus was
allowed prior to data collection in order to avoid such a limitation (Wilkins, Valovich-
McLeod, Perrin, Gansneder, 2004). Therefore, the findings of the study should not be dismissed under the guise of a learning curve.

The intent of the researchers is to apply these initial findings to a physical therapy protocol involving an elderly cohort as a means of strengthening the individual without compromising neuromuscular balance. The scope of our focus is clear given that falls are a leading cause of injury among elderly adults (Masud & Morris, 2001) and that the eccentric activity of descending stairs outnumbers falls from the concentric activity of ascending stairs by a ratio of 3:1 (Startzell, Owens, Mulfinger, Cavanagh, 2000). A blatant limitation of such an application within an elderly cohort may be attributed to the inability of a researcher to simulate reflexive co-contraction which naturally results from unanticipated, external stimuli, (Llewellyn, Yang & Prochazka, 1990; Nielsen & Kagamihara, 1992) such as a fall or a near fall. This must be addressed within any methodology that attempts to use its findings to aid an elderly cohort in decreasing fall risk, while attenuating the sarcopenic effects of primary aging. Recently, LaStayo, Ewy, Pierotti, Johns & Lindstedt (2003) reported that eccentric exercise does, in fact, decrease the fall risk of an elderly cohort while requiring little energy expenditure thus making the recommendation of such prescriptions applicable. More research must be performed regarding these benefits to ensure that such exercise prescriptions are not predisposing participants to greater risks than are potentially attenuated.

Clearly, there are fundamental discrepancies within the body of current literature that must be reconciled if we are to prescribe therapies and exercise protocols that are in the best interest of the client’s recovery and prevention of future injury.
REFERENCES


APPENDIX

Institutional Review Board
Consent and Authorization Document

BACKGROUND
You are being asked to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with friends and relatives if you wish. Ask the research doctor or staff if there is anything that is not clear or if you would like more information. Take time to decide whether or not to volunteer to take part in this research study. The aim of this study is to investigate the impact of lower extremity fatigue on neural connections, as measured by the signal response produced from a given stimulus. Additionally, we will observe fatigue’s effect on postural stability, as measured by the amount of sway that you have while standing still and leaning towards specified directions. The data will be obtained with the use of skin monitors that will be placed on the back of your calf. The fatigue protocol will consist of 1x10-minute set of lower extremity eccentric contraction. The aims of the study are to examine contradictions in the literature regarding fatigue's effects. Findings of this research will have general application in a variety of conditions, including but not limited to: aging, disease, and injury.

STUDY PROCEDURES
While being examined, you will be placed in a prone position, face down, with your feet flat against a wall or other straight surface. Electrical stimuli will be administered and monitored graphically. When a peak response is observed (the highest magnitude on the graph), we will have obtained the necessary data to evaluate how you respond, neurally, to a given strength of stimulus. Next, you will perform a baseline stability task by leaning in multiple directions with a computer analyzing your sway both while moving and standing. Following both exams, you will resist a biking machines pedal movements for 2 ten minute sets. Following the fatigue protocol, your balance and neural communication exams will be performed again to assess the immediate impact of fatigue and then to monitor that impact for 5-15 minutes. You will not have to do any follow-up visits.

RISKS
Hyperextension of knee during eccentric contraction fatigue protocol. However, this result is unlikely, as you will be instructed not to approach full knee extension and will be monitored during the fatigue protocol to ensure this is adhered to. Following testing, you may experience slight skin irritation from the electrodes. This irritation should subside within 24 hours and may be decreased by the application of a skin moisturizer. Due to the use of electrical stimulation, there may be a slight level of discomfort associated with the testing. It is also important to note that a very small percentage of subjects experience dizziness, nausea, and fainting associated with this mode of testing. You will
be encouraged and reminded to alert the investigator if any of these symptoms appear. Due to the use of electrical stimulation and the risk of electrical shock, there are two devices (stimulation isolation unit, and constant current unit) placed in the circuit between you and the stimulator, which greatly decrease the chances of receiving a harmful shock. This type of nerve stimulation is common and considered to be safe for human subjects. Additionally, there is a risk that your personal information can be lost or stolen during the course of the study.

BENEFITS
There are no direct benefits for taking part in this study. However, we hope the information we get from this study may help develop a greater understanding of muscle fatigue in the future.

CONFIDENTIALITY
The results of this study will not reveal your name in any way. In fact, you will be assigned a numeric code and that will be used to reference your results during our data collection. Your information will be stored on a password-protected computer and will be held for 3 years, after which your personal details, along with the data we collect, will be destroyed.

PERSON TO CONTACT
If you have questions, complaints or concerns about this study, you can contact Joshua Irvine at 801-809-9653. If you feel you have been harmed as a result of participation, please call Bradley Hayes, Ph. D., ATC at 801-585-1820 who may be reached during 8am and 5pm daily.

INSTITUTIONAL REVIEW BOARD
Contact the Institutional Review Board (IRB) if you have questions regarding your rights as a research participant. Also, contact the IRB if you have questions, complaints or concerns which you do not feel you can discuss with the investigator. The University of Utah IRB may be reached by phone at (801) 581-3655 or by e-mail at irb@hsc.utah.edu.

VOLUNTARY PARTICIPATION
Your participation in this study is completely voluntary and any desire to discontinue participation, at any time during the study, will not involve any penalty to you.

COSTS AND COMPENSATION TO PARTICIPANTS
Participation in this study will not cost you any money. In addition, you will not receive any compensation for participating in the study.
NUMBER OF PARTICIPANTS
The study will examine approximately 40 college-age adults. The study is not part of a national investigation.

AUTHORIZATION FOR USE OF YOUR PROTECTED HEALTH INFORMATION
Signing this document means you allow us, the researchers in this study, and others working with us to use information about your health for this research study. You can choose whether or not you will participate in this research study. However, in order to participate you have to sign this consent and authorization form.
This is the information we will use:
- Name
- Address
- Telephone number

Others who will have access to your information for this research project are the University's Institutional Review Board (the committee that oversees research studying people).

Others who will have access to your information for this research project are the University's Institutional Review Board (the committee that oversees research studying people) and authorized members of the University of Utah Health Sciences Center who need the information to perform their duties (for example: to provide treatment, to ensure integrity of the research, and for accounting or billing matters).

You may revoke this authorization. This must be done in writing. You must either give your revocation in person to the Principal Investigator or the Principal Investigator’s staff, or mail it to Bradley Hayes, Ph.D., ATC at 250 South 1850 East Rm 200, SLC, UT 84112. If you revoke this authorization, we will not be able to collect new information about you, and you will be withdrawn from the research study. However, we can continue to use information we have already started to use in our research, as needed to maintain the integrity of the research.

You have a right to information used to make decisions about your health care. However, your information from this study will not be available during the study; it will be available after the study is finished.

This authorization lasts until this study is finished.

CONSENT
I confirm that I have read this consent and authorization document and have had the opportunity to ask questions. I will be given a signed copy of the consent and authorization form to keep.

I agree to take part in this research study and authorize you to use and disclose health information about me for this study, as you have explained in this document.

Participant’s Name

Participant’s Signature Date

Name of Person Obtaining Authorization and Consent

Signature of Person Obtaining Authorization and Consent Date

If the participant is unable to give consent and authorization, consent and authorization is given by the following authorized personal representative of the individual:

Name of Authorized Personal Representative

Signature of Authorized Personal Representative Date

If the participant is unable to give authorization and consent, indicate the legal representative’s authority to act for the individual:

☐ Spouse
☐ Adult (18 years of age or over) for his or her parent
☐ Individual with power of attorney
☐ Guardian appointed to make medical decisions for individuals who are incapacitated
Title of Research Project:
Immediate effects of muscular fatigue on postural stability and motoneuron pool excitability in healthy adults.

Investigator:
Bradley T. Hayes Ph.D., ATC. Department of Exercise and Sport Science
Lee Dibble Ph.D., PT, ATC Division of Physical Therapy
Joshua C. Irvine Undergraduate Research Assistant

Purpose of Research Project:
The aim of this study is to investigate the impact of lower extremity fatigue on afferent/efferent connectivity, as quantified by the H-reflex (Hoffman-reflex) and on postural stability, as measured by the percent endpoint excursion and max excursion, being evaluated with a limits of stability examination. The data will be obtained with the use of cutaneous electrodes placed on the posterior soleus. The fatigue protocol will consist of 1x10-minute bout of lower extremity eccentric contraction. The aims of the study are to examine contradictions in the literature regarding fatigue’s effects. Findings of this research will have general application in a variety of conditions, including but not limited to: aging, disease, and injury.

Procedure:
I understand that as a participant in this study:
• I will be asked to participate in one data collection that will last approximately 2 hours.
• I will have my spinal reflexes tested according to the procedures listed below.

Reflex Testing Protocol
During the testing, I will be undergoing spinal reflex testing that involves having an electrical stimulation delivered to the back of my leg while prone (on my stomach). The stimulation will cause a reflex contraction of the muscles in my leg that will be measured by electrodes placed over those muscles. The reflex will be measured several times over the course of each testing session and there will be at least a 10 second pause between each stimulus.

This type of stimulation has been compared to a feeling like a carpet shock (build-up of static electricity that is transferred once I touch a grounding element). If at any time I want to stop the testing, I am able to do so without question by notifying the research assistant.
The equipment used in this experiment contains special safety devices that limit the chances of me being injured from electrical shock or stimulation.

Foreseeable Risks or Discomforts:

- Following testing, I may experience slight skin irritation from the electrodes. This irritation should subside within 24 hours and may be decreased by the application of a skin moisturizer (which will be available in the Laboratory).
- Due to the use of electrical stimulation, there may be a slight level of discomfort associated with the testing. It is also important to note that a very small percentage of subjects experience dizziness, nausea, and fainting associated with this mode of testing. Therefore, I will be encouraged and reminded repeatedly to alert the research assistant if I experience any of these symptoms.
- Due to the use of electrical stimulation, the risk of electrical shock is present. There are two devices (the stimulation isolation unit and the constant current unit) placed in the circuit which greatly decrease the chances of receiving a harmful shock. This type of nerve stimulation is common and considered to be safe for human subjects.

Benefits to be expected from the Research:

- There are no direct benefits from participation in this study

Compensation

- I understand that I will not receive any direct compensation from participation in this study

Confidentiality

- I understand that any information obtained in connection with this study that can be identified with me will be kept confidential to the extent permitted by law. A code number will be used to identify any test results or other information I provide. Neither my name nor any information from which I might be identified will be used in any data summaries or publications. Following the publication of the data from this project, the principal investigator will destroy all measurements, including measurements from subjects who withdrew.

Compensation for Injury

- I understand that the University does not provide a research subject with compensation or medical treatments in the event that the subject is injured as a result of participation in the research project
Voluntary Participation Statement

- I understand that my participation in this study is completely voluntary and that I may either refuse to participate or withdraw from the study at any time without penalty.

If you have Questions

- I understand that any questions I have about the research study or specific procedures should be directed to Bradley T. Hayes Ph.D., ATC at (801) 884-7900.

- If I have questions about my rights as a research subject, I should contact the IRB Coordinator at 581-3655.

My signature below indicates that I have read and understand the procedures described above and therefore, give my informed and voluntary consent to participate in this study. I understand that I will receive a signed copy of this consent form.

Signature of Subject: ____________________________

Name of Subject (print): ____________________________

Date Signed: __/__/____
Name of Candidate: Joshua Caleb Irvine

Birth Date: September 28, 1983

Birth Place: Provo, Utah

Address: 12674 South Natalie Drive
        Riverton, Utah, 84065