Spinal reflex alterations following acute ankle sprains

Robyn E. Hafner

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entitled

Spinal Reflex Alterations Following Acute Ankle Sprains

by

Robyn E. Hafner

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the

Master of Science Degree in Exercise Science

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May 2012
Context: Lateral ankle sprain is the most common lower extremity injury in sport. It is well documented that previous ankle sprains can predispose an individual to future injuries and is hypothesized that altered input from the damaged ligaments may inhibit motor neuron pool excitability and lead to diminished muscle activation and chronic weakness of surrounding muscles. This phenomenon, known as arthrogenic muscle inhibition (AMI), can be a limiting factor in rehabilitation and the pathways involved with these neuromuscular deficits are not completely understood. Objective: Determine the effect of acute LAS on reflex excitability of lower leg musculature over a 14 day period compared to healthy matched controls. Additionally, to determine the relationship between H-reflex and dynamic postural control, self-reported measures of function and pain in individuals with LAS within 36 hours of injury. Design: Case-Control. Setting: Clinical Laboratory. Participants: Eight patients with acute lateral ankle sprain (3 males, 5 females; age= 21±1.85 years, height=174.63±9.77 cm, mass=73.81±19.56 kg) and eight healthy participants (3 males, 5 females: age=20.38±1.60 years, height=173.99±9.21 cm, mass=73.98±17.87 kg) volunteered to participate in this study. All participants were individuals from the University community. Interventions: All participants reported for
a total of 5 test sessions at 36 hours, 5, 7, 10, and 14 days following the initial ankle sprain; or from the day of enrollment as a healthy control. Spinal reflexive excitability of the lower leg musculature was assessed bilaterally in each participant as well as self-reported function and pain, and dynamic balance. **Main Outcomes:** For each lower leg muscle’s spinal reflex excitability, a repeated measures 2x5 ANOVA was used to determine if differences existed between groups over time. Spearman’s rho correlation coefficients were calculated in the injured group between measures of lower leg spinal reflex excitability and self-reported disability, pain, function, and dynamic stability, at 36 hours following the initial injury. Alpha levels were set a priori at $P \leq 0.05$ **Results:** A significant main effect for group was found in Soleus spinal reflexive excitability ($F(1,13)=.182, p=0.011$). A significant correlation was found between FL and function at 36 hours ($r=.733, r^2=.545, p=.025$). **Conclusion:** Our results were similar to previous studies investigating differences in lower leg excitability in individuals with functional ankle instability. We found a significant correlation between function and FL only; however, because spinal reflex excitability is not the only factor associated with determining function, future studies should consider other factors such as ankle range of motion and girth measurements to quantify swelling. Those who suffer an acute LAS exhibit decreased spinal reflex excitability compared to healthy counterparts within two-weeks of the initial injury. While studies investigating the acute alterations in spinal reflexes of the lower leg muscles are limited, these results should be taken into consideration in ongoing treatment of acute lateral ankle sprains. **Word Count:** 459
To all of the people who believed in me throughout the past two years, thank you! I wouldn’t have been able to complete this without your continued efforts and wise words.

To my roommates of GA World, I love you all. (No I don’t you’re all a bunch of knobs).

And last but not least, my sweet little Sarge, you’re the best!
Table of Contents

Abstract ........................................................................................................................................ iii

Table of Contents ............................................................................................................................... v

List of Tables .................................................................................................................................... vii

List of Abbreviations ....................................................................................................................... viii

1 Chapter 1 ...................................................................................................................................... 1

1.1 Introduction ............................................................................................................................... 1

1.1.1 Problem Statement .................................................................................................................. 2

1.1.2 Purpose Statement .................................................................................................................. 3

1.1.3 Dependent Variables .............................................................................................................. 3

1.1.4 Independent Variables .......................................................................................................... 3

1.1.5 Hypotheses ............................................................................................................................ 3

1.1.6 Operational Definitions ....................................................................................................... 4

2 Chapter 2 ...................................................................................................................................... 5

2.1 Literature Review ....................................................................................................................... 5

2.1.1 Lateral Ankle Sprain ............................................................................................................. 5

2.1.2 Arthrogenic Muscle Inhibition ............................................................................................. 6

2.1.3 Hoffman Reflex .................................................................................................................... 7

3 Chapter 3 ...................................................................................................................................... 12

3.1 Methodology ............................................................................................................................. 12

3.1.1 Participants ........................................................................................................................ 12

3.1.2 Procedures .......................................................................................................................... 13
List of Tables

A.1 Demographics ........................................................................................................25
A.2 Main Effect for Time .............................................................................................25
A.3 Main Effect for Group ..........................................................................................25
A.4 Descriptive Statistics ............................................................................................26
A.5 Correlations ..........................................................................................................26
List of Abbreviations

LAS…………………Lateral Ankle Sprain
ATF…………………Anterior Talo-fibular Ligament
CF…………………..Calcaneofibular Ligament
PTF………………….Posterior Talo-fibular Ligament
AMR………………..Arthrogenic Muscle Response
AMI………………...Arthrogenic Muscle Inhibition
SEBT……………….Star Excursion Balance Test
VAS…………………Visual Analog Scale
FADI………………..Functional Ankle Disability Index
FAI………………….Functional Ankle Instability
NT…………………..Neurotransmitter
MN…………………Motoneuron
NM…………………Neuromuscular
TA…………………...Tibialis Anterior
FL…………………...Fibularis Longus
SOL…………………Soleus
EMG………………..Electromyography
Chapter 1

Introduction

Ankle sprains are the most common injury in sports, consisting of 38-45% of all injuries.\textsuperscript{1-3} A lateral ankle sprain (LAS) is described as the result of stretching or tearing of the fibers of the anterior talo-fibular (ATF), calcaneofibular (CF) and posterior talo-fibular (PTF) ligaments.\textsuperscript{1,2} LAS can occur due to excessive supination and inversion of a plantarflexed foot while the tibia is externally rotated. While often viewed as a mild injury, it is well documented that previous ankle sprains can predispose an individual to future injuries.\textsuperscript{1,2} Damage to mechanoreceptors within the lateral ankle ligaments after injury is hypothesized to interrupt neurological feedback mechanisms as afferent inputs to the spinal and cortical levels are altered. This altered input may inhibit motor neuron pool excitability and lead to diminished muscle activation and chronic weakness of surrounding muscles, which may contribute to resultant instability at the ankle.\textsuperscript{4}

The phenomenon of altered muscle activation following joint injury is commonly termed arthrogenic muscle response (AMR). It is a natural response of the body that is intended to protect the injured joint from further harm.\textsuperscript{5} However, if persistent, AMR can be a limiting factor in rehabilitative gains of strength and neuromuscular control.\textsuperscript{2} Arthrogenic muscle inhibition (AMI) has been reported in patients with knee injuries,\textsuperscript{6-8}
as well as with ankle instability, yet the pathways involved with these neuromuscular deficits are not completely understood. AMI plays a major role in the injury cycle by contributing to immobilization, muscle wasting, muscle weakness and increases susceptibility to further injury. Following joint injury, immobilization in the form of range of motion and movement deficits can occur. Immobilization can result from pain, swelling, muscle spasm and/or the affected joints musculature’s inability to contract normally and therefore, when persistent, leads to muscle wasting and weakness.

Limited studies have investigated spinal reflex excitability immediately following acute LAS or artificial effusion but no studies have observed changes in spinal reflex excitability in the post acute phase of injury.

A previous study that investigated the spinal reflex response following an artificial ankle effusion observed increased neural excitability of the soleus, peroneus longus, and tibialis anterior musculature as measured using the Hoffmann (H) reflex. The authors explained that this was likely a protective arthrogenic muscle response in order to prevent the ankle from moving into a dorsiflexed position via co-contraction of the surrounding ankle joint musculature. While this does not coincide with the previously described mechanism for AMI it is a potential mechanism that warrants further investigation.

Additionally, there is limited evidence that investigates the spinal reflex response following acute ankle sprain. In this study, delayed latency periods were observed in the flexor digitorum longus and fibularis longus muscles compared to the contralateral limb following acute ankle sprain, indicating a decrease in neural excitability. Alterations in spinal reflex activity remain relatively unknown following
acute ankle sprain as the existing literature\textsuperscript{11} does not take into account pain, amount of swelling, and damage to capsuloligamentous and neural tissue following acute ankle sprain that may alter neuromuscular function to a greater degree than that of an artificial effusion of a healthy individual.\textsuperscript{12}

**Problem Statement**

Although limited research has been conducted investigating the effects of an artificial effusion and acute ankle sprain on spinal reflex excitability, findings are inconsistent and remain poorly understood. Therefore, looking at outcome measures over a 14 day period following an acute LAS will allow us to determine the effects that a LAS has on spinal reflex excitability over the course of healing.

**Purpose Statement**

The primary purpose of this study was to determine the effect of acute LAS on reflex excitability of lower leg musculature as measured using the H-reflex over a 14 day period compared to healthy matched controls. Additionally, we examined if there is a relationship between H-reflex, dynamic postural control, self-reported measures of function and pain in individuals with LAS within 36 hours of injury.

**Dependent Variables**

- Hoffman (H) reflex
- Visual Analog Scale (VAS) for self-reported ankle function index
- Visual Analog Scale (VAS) for self-reported pain index
- Global Function
- Star Excursion Balance Test (SEBT)
Anterior Reach Direction
Posterior Medial Reach Direction
Posterior Lateral Reach Direction

Independent Variables

• Group (LAS/control)
• Limb (injured/non-injured)
• Time (36 hours, 5 Days, 7 Days, 10 days, and 14 Days post-injury/enrollment in the study)

Hypotheses

1. LAS would exhibit decreased spinal reflex excitability compared to a control group.
2. A positive relationship would be observed between level of function and measures of reflex excitability.
3. A positive relationship would be observed between lower extremity musculature spinal reflex excitability and measures of dynamic postural control.

Operational Definitions

• AMI: Arthrogenic Muscle Inhibition is the phenomenon of altered muscle activation following an injury to a joint.
• FADI: Functional Ankle Disability Index is a self-reported questionnaire of functional deficits during activities of daily living and sport/physical activities.
• Hoffmann (H) reflex: an electrically induced monosynaptic reflex that is used to
measure spinal reflex excitability.

- Acute Ankle Sprain: For the purposes of this study, an acute ankle sprain is defined as stretching or tearing of the fibers of the anterior talo-fibular (ATF), calcaneofibular (CF) and posterior talo-fibular (PTF) ligaments.
- SEBT: Star Excursion Balance test is used to assess dynamic postural control.
Chapter 2

Literature Review

Lateral Ankle Sprains

Eighty five percent of ankle sprains\textsuperscript{13} affect the lateral aspect of the ankle. It is well known that previous ankle sprains is a risk factor for subsequent ankle sprains and chronic ankle instability\textsuperscript{1,2,14}. Altered feedback from joint damage or edema can negatively affect dynamic stabilization; thus increasing susceptibility to further injury\textsuperscript{15}.

An ingrained pattern of inversion of the hind foot develops in chronically unstable ankles and is observed with walking and emphasized with running.\textsuperscript{16} This repetitive overloading of the medial surfaces of talus and tibia leads to progressive degenerative wearing of the medial talus in people with instability.\textsuperscript{16}

Damage to mechanoreceptors within lateral ankle ligaments after injury is hypothesized to interrupt neurologic feedback mechanisms resulting in functional ankle instability (FAI).\textsuperscript{4} FAI may be present in up to 40% of patients after LAS,\textsuperscript{4} and there is commonly a report of the ankle “giving way”.\textsuperscript{13} This altered input can lead to chronic weakness of muscles surrounding a joint, also known as arthropgenic muscle inhibition (AMI), which may contribute to FAI.
Arthrogenic Muscle Inhibition

Arthrogenic muscle inhibition (AMI) is a presynaptic, ongoing reflex inhibition of musculature surrounding a joint after distension or damage to structures of that joint.\textsuperscript{15,18} Joint receptors are specialized cells that change their properties in response to specific stimuli of various types. They have 2 major functions 1) Provide position sense or information about relative configuration of body segments. 2) To initiate protective reflex mechanisms that protects and helps stabilize the joint. The most influential factor associated with AMI is a change in afferent input to the spinal cord from the joint.\textsuperscript{5} Inhibition is a very common regulatory occurrence within the neuromuscular system. Inhibition in the nervous system is either pre- or postsynaptic. Synapses between neurons or between neuron and membrane are either excitatory or inhibitory. Both result in release of a neurotransmitter (NT). The NT crosses synaptic cleft to bind to specific receptor on postsynaptic membrane; causing excitatory or inhibitory potentials. AMI can be caused by increased afferent activity, evidenced by effusion and an apparent lack of afferent activity, such as with ligamentous rupture.\textsuperscript{5}

Reversing AMI may not assist in protecting the ankle from further instability episodes, but dynamic muscle activation should be restored to maximum stabilization. Integrating active exercise early in joint rehabilitation is necessary for decreased healing time, increased vascular growth, quick regeneration of scar tissue and stronger ligament and tendon healing. Therefore, it is important for clinicians, such as athletic trainers, to understand AMI in order to find ways to overcome inhibition that is preventing strength gains.
The limiting factor in joint rehabilitation is not only pain but also the neurophysiologic response of joint mechanoreceptors.\textsuperscript{5,20} AMI is a reduction in motoneuron (MN) pool recruitment. One way of measuring this reduction in MN pool recruitment is through Hoffman (H) reflex testing, which will be discussed in full later.

Overall, AMI is a limiting factor in rehabilitation of joint injury, which may result in strength deficits that can persist long after healing has occurred. Clinicians should be aware of the factors associated with AMI for this reason. AMI also causes atrophy and can lead to premature return to play and increased susceptibility for re-injury. Educating patients about this is necessary so they can understand the risk of premature return to play and the potential for re-injury.

**Hoffman-Reflex**

The Hoffman (H) reflex is a measure of MN pool recruitment. Electrical stimulation of a mixed nerve evokes 2 electromyographical responses from respective muscles. One response (H-reflex) to the electrical stimulus is an action potential which is the result of primary afferent stimulation which excites MNs in the anterior horn of the spinal cord.\textsuperscript{2} Begin with a low intensity stimulus and as the h-reflex increases, more afferent fibers are recruited as they begin to reach their threshold, resulting in activation of more MNs. As the stimulus’ intensity is increased, a second response, the M-response, appears. This response is representative of a direct stimulation of efferent MN fibers. The H-reflex represents the portion of MN pool that was stimulated from afferent activity and inhibition results in a decrease in MN pool excitability.\textsuperscript{5} Estimates of alpha motoneuron excitability and its peak value represent maximal reflex activation.\textsuperscript{9} If motoneuron activation is depressed, output capacity of muscle is minimized and muscle activation is
decreased. Normalized as maximal M-response (H:M ratio) which is representative of entire motoneuron pool of muscle being studied. To elicit the H-reflex, a percutaneous electrical stimulus is applied to a mixed nerve. Keep in mind the length of H-reflex pathway when examining amount of time it takes for H-reflex to appear on EMG. The time depends on how close the muscle is in relation to the spinal cord.

One potential problem in the evaluation of H-reflex is that crossed spinal pathways transmit information to the contralateral leg which might inhibit the joint musculature of that leg, in addition to the involved limb. This suggests that AMI may be present in both limbs and therefore more difficult to determine. The measurement can vary with head and body posture, foot position, eye movement and remote muscle contractions. Under controlled conditions and within same subject, it is very reliable between measurements and days. The reliability also depends on electrode placement. Since the electrode placement will rarely be in the exact same position, it is often necessary to normalize the H-reflex. The most common way to do so is through \( \frac{H_{\text{max}}}{M_{\text{max}}} \) ratio.

H-reflex is a valuable tool to evaluate neurologic function. Care must be taken when eliciting the H-reflex because of the sensitivity of the measurement to extraneous factors. H-reflex is an electrically induced reflex analogous to the mechanically induced spinal stretch reflex. The difference between H-reflex and spinal stretch reflex is that H-reflex bypasses muscle spindle and is valuable tool to assess modulation of monosynaptic reflex activity in the spinal cord. Estimate of alpha motoneuron excitability when presynaptic inhibition and intrinsic excitability of MNs remain constant. Electric stimulation to elicit H-reflex measures efficacy of synaptic transmission as stimulus
travels in afferent fibers through MN pool of corresponding muscle to efferent fibers. Electric stimulation of peripheral nerve causes direct activation of efferent fibers and sends action potentials directly to neuromuscular junction (NM).

Increasing stimulus intensity beyond that required for H-reflex results in direct stimulation of motor axons and denotes presence of M-wave. Action potentials are generated and fired toward NM junction when the stimulus intensity reaches the depolarization threshold for the efferent fibers which causes muscle contraction. Since the stimulus didn’t pass through spinal cord, it is not a reflex; but instead it is a muscle response (M-wave). Delivering the stimuli too close together decreases the amplitude of H-reflex because of previous activation in afferents and depletion of neurotransmitters. To reduce this likelihood of post activation depression, the stimuli should be given 10 seconds apart.

Previous studies have examined the effects of LAS on lower leg muscles of soleus, fibularis longus and tibialis anterior. One study examined whether AMI was present in soleus, fibularis and anterior tibial muscles of patients exhibiting unilateral FAI. The study compared H:M ratios in unstable limb to stable limb. Two cross sectional designs were used to 1) evaluate effect of side (affected/unaffected) on soleus, fibularis and anterior tibial muscle H:M ratio in patients with FAI, 2) evaluate the effect of side (R/L) on those 3 muscle H:M ratios in healthy control participants. Their results suggest that lower H:M ratios in fibularis (p=0.041) and soleus (p=0.035) muscles exist in the affected limb when compared to unaffected limb, which suggests AMI is present in the limb exhibiting FAI. Among uninjured subjects, side-to-side H:M ratios were not
found to be different which strengthens the notion that lower H:M ratio in functionally unstable ankles is result of AMI.

The objective of another study 10 was to determine if AMI is present in soleus, peroneus longus and tibialis anterior after simulated ankle joint effusion. Maximum H-reflex and m-wave measurements were collected using EMG after the delivery of a percutaneous stimulus to the sciatic nerve before its bifurcation into common peroneal and posterior tibial nerves. The results were H-reflex and m-wave measurements in all 3 muscles increased after simulated ankle joint effusion which resulted in facilitation of motoneuron pools. The authors suggest that this facilitation may occur to stabilize the foot and ankle complex to maintain postural control and/or locomotion. 10

Another study 21 examined changes in quadriceps and soleus MN pool activity resulting from artificial effusion and assessed the relationship between the muscles. Following the effusion, soleus and vastus medialis H-reflex measures were collected before, at 30 min, 90 min, 150 min and 210 min intervals over 4 hr period. All soleus H-reflex measures after effusion were increased in relation to pre-effusion measures. All vastus medialis H-reflex measures were decreased in relation to pre-effusion measures. Afferent activity from knee joint capsule resulted in inhibitory effect on the vastus medialis and a facilitatory effect on soleus. This facilitatory effect could be a mechanism for compensation of the inhibited quadriceps to maintain lower kinetic chain function.

The objective of a study 15 by Hopkins was to quantify muscle activation in fibularis longus, tibialis anterior and soleus and determine ankle joint peak torque, peak power and root mean square power during closed kinetic chain activity following simulated ankle effusion. The results were; average and peak peroneus longus EMG
decreased immediately after effusion, average EMG remained depressed 30 minutes after effusion. Post-effusion; decrease in ankle torque was detected. No differences were found in tibialis anterior or soleus EMG, power or root mean square power. Decreases in ankle plantarflexion torque and peroneus longus EMG suggest a NM deficit exists in the presence of edema which could increase susceptibility for further ankle injury.
Chapter 3

Methodology

Participants

Eight injured participants (3 males, 5 females; age= 21±1.85 years, height=174.63±9.77 cm, mass=73.81±19.56 kg) and eight healthy participants (3 males, 5 females: age=20.38±1.60 years, height=173.99±9.21 cm, mass=73.98±17.87 kg) were recruited from the university community to participate in this case-control study. Prior to participation, all participants read and signed an informed consent form approved by the University of Toledo Institutional Review Board. None of the participants had a vestibular disorder, or previous history of fracture or surgery to their ankles. We also excluded those with concussion or head injury in the past 6 months, history of stroke, cardiac condition, cancer in the thigh musculature, or a cardiac pacemaker, implanted cardiac defibrillator or were currently pregnant/breastfeeding. Patients in the ankle sprain group were included if they presented with an acute LAS with swelling, pain, and temporary loss of function within 36 hours of the initial injury, and had no previous injury to the lower extremity other than that same ankle in the previous six months.

Our healthy, matched controls had no previous injury to the ankle, knee, or hip and were recruited following the enrollment of an acute LAS participant. Participants
were matched according to sex, age, height, mass and limb dominance. The dominant limb was designated as the leg with which they would prefer to kick a ball. After these factors were matched, the limbs of the control participants were matched to the acute LAS participants by designating an “injured” leg with the same leg of the respective matched Acute LAS participant. For instance, if the injured side of an Acute LAS participant was the right side, then the matched “injured” side of the matched Control participant was also the right side. This helped to avoid the potential issues of unmatched comparisons of limb dominance that could occur with randomizing the limb assignment in the Control group.

**Procedures**

All participants reported for a total of 5 test sessions at 36 hours, 5, 7, 10, and 14 days following the initial ankle sprain; or from the day of enrollment as a healthy control. Each session lasted approximately 1 hour. Spinal reflexive excitability of the lower leg musculature was assessed bilaterally in each participant as well as self-reported function and pain, and dynamic balance. Rehabilitative activities were also logged throughout the duration of the study. A description of each of these measures follows.

**Spinal Reflex Excitability**

Participants were instructed to lie prone on a padded treatment plinth located in the University of Toledo Athletic Training Room. The head of each participant rested comfortably in the face rest of the plinth with their knees slightly flexed (~10-15°) and arms resting comfortably beside their head. The areas over the recording electrode sites were shaved, debrided gently with sand paper, and wiped cleaned with an alcohol wipe. Two 10mm, pre-gelled Ag-AgCl (EL503, BIOPAC Systems Inc, Goleta CA, USA)
Surface electromyography electrodes were positioned 2 cm apart over the muscle belly of interest. These measurements were taken from lower leg musculature including: soleus (SOL), tibialis anterior (TA), and fibularis longus (FL). Electrodes were placed 2-3 cm (2 finger widths) distal to the medial head of the gastrocnemius for the SOL. The TA electrodes were placed at the midbelly of the muscle and the FL electrodes were placed 2-3 cm (2 finger widths) distal to the fibular head.

A 2 mm shielded disc stimulating electrode (EL2524S, BIOPAC Systems Inc., Goleta CA, USA) was positioned and secured with hypoallergenic tape over the sciatic nerve at the posterior aspect of the knee, prior to its split into the common peroneal and tibial nerves. A 7x13 cm self-adhesive electrode was positioned over the quadriceps and used as a dispersive electrode. A 1 ms square wave stimulus was produced with a BIOPAC stimulator module (STM100A, BIOPAC Systems, Inc., Goleta CA, USA) and a 200 volt maximum stimulus adaptor (STMISOC, BIOPAC Systems Inc., Goleta CA, USA) and delivered to the sciatic nerve.

During testing participants were instructed to maintain a constant head, eye and hand position by focusing on a spot on the carpet. The stimulus was increased in 0.2 volt increments until a maximum H-reflex was elicited; 3 maximal H-reflexes were then recorded. The stimulus was subsequently increased until a maximal muscle response (M-wave) was elicited, followed by the recording of 3 maximal elicited M-waves. The values of these peak amplitudes were normalized as a ratio (H: M) and used to represent motor neuron pool excitability in our analyses.

**Functional Ankle Disability Index**
All participants completed the Functional Ankle Disability Index (FADI) and the FADI Sport at each session. These paper instruments provided information on the presence of subjective deficits related to ankle instability. There are 26 items on the FADI; all of which are related to activities of daily living and pain and there are 8 items on the FADI Sport; all of which are related to participation in physical activity. The FADI has a total point value of 104 points, whereas the FADI Sport has a total point value of 32 points. The FADI and FADI Sport are scored separately as percentages, with 100% representing no dysfunction. Both instruments have been shown to have strong reliability and moderate to high sensitivity.\(^1\)

**Star Excursion Balance Test (SEBT)**

The intra-rater (ICC:0.78-0.96)\(^2\)\(^10\)\(^11\) and reliability of the SEBT is strong, making it a viable tool for assessing dynamic postural. This task required the participant to place a foot in the middle of the testing grid while moving the opposite limb to reach as far as possible in the designated reaching direction keeping their hands on their hips and the heel flat on the floor. When maximum reaching distance was achieved, the participant made a light touch on the tape line with the most distal part of the foot, and then returned the reaching limb back to the center of the testing grid without shifting their weight to the reaching limb and without compromising the base of support established by the stance/test limb. If the participant was judged to make a heavy touch, pushed off the ground with the reaching limb, had to shift the foot position of the stance limb, or touched the ground with the reaching limb while returning back to the middle of the testing grid, the trial was discarded and repeated. A member of the study team was
available to spot each participant and prevent fall in case the study participants lost their balance.

After the Primary Investigator (PI) demonstrated the reaching task in each of the three directions (anterior, posterior medial and posterior lateral) to the participant, participants performed 4 practice trials in each of the reaching directions using the right and left limbs before initiating the test trials to minimize the learning effect. After the 12 practice trials were completed, they were afforded a five minute rest period. The participant performed 3 test trials in each reaching direction using the involved stance/testing limb. Reach direction was counter-balanced prior to the test session. The investigator marked and recorded the reach distances on the testing grid with the average of the trials recorded. The reach distances, in cm, were normalized by dividing the reach distance by the participant’s leg length to create a dependent variable that represents normalized maximum reach distance, reported as a percentage, for each of the three reach directions. Leg length was measured, as the distance from the ASIS to the middle of the medial malleolus with the participant lying supine on a table.

**Visual Analog Scale**

Participants were handed a paper with 3, 10cm lines marked separately for pain, ankle function, and global function. The left end of each line indicated the lesser degrees of pain or functional restriction that they were currently experiencing, while the right side indicated the greater amounts of pain or functional restriction. At each testing session, participants were asked to stand while filling out the form and to make a vertical mark along each line indicating how they felt relative to each category, at that point in time.

**Treatment Questionnaires**
Participants were handed a paper with a series of questions related to treatment of their acute ankle sprain including: medication use, therapeutic modalities (i.e. ice, electrical stimulation, and ultrasound), frequency of therapeutic exercise, and participation in sport specific practice and game activity. Additionally, they were asked to provide a rating of their overall perceived level of global function as a percentage (0-100).

Statistical Analysis

Means and standard deviations for all H-reflex measures were used for statistical comparison. For each lower leg muscle’s spinal reflex excitability, a repeated measures 2x5 ANOVA was used to determine if differences existed between groups over time. Spearman’s rho correlation coefficients were also calculated in the injured group between measures of lower leg spinal reflex excitability and self-reported disability, pain, function, and dynamic stability, at 36 hours following the initial injury. All statistical analyses were performed using SPSS 17.0 (SPSS Inc., Chicago, IL) statistical software package. Significance was set a priori at P<0.05.
Chapter 4

Results

There were no differences in demographics of the LAS group and the control group (p>.05) (Table 1). Furthermore, no significant differences were found in spinal reflexive excitability of the injured TA or FL between groups (Table 3) or over time (Table 2). A significant main effect for group was found in SOL spinal reflexive excitability (F\(_{1,13}\)=.182, p=0.011) (Table 3), however no differences were observed over time.

No significant relationships were observed between lower leg spinal reflexive excitability and self-reported function, pain, or dynamic balance (Table 5). A significant correlation was found between FL and function at 36 hours (r=.733, r\(^2\)=.545, p=.025) (Table 5).
Chapter 5

Discussion

The purpose of this study was to determine if there were differences in spinal reflex excitability of the lower leg musculature in people who suffered an acute LAS compared with healthy matched controls. No differences were found between the injured limbs of the two groups, or over a two week period in spinal reflex excitability of the tibialis anterior or fibularis longus muscles. Differences existed in soleus spinal reflex excitability between groups; however, there were no differences in soleus excitability over time within each group.

This study is unique because participants were tested at several time-points over a two-week period. H:M ratios of the soleus were smaller in the injured group compared to the healthy group, in the injured limb. Our results differ from Klykken et al.\textsuperscript{12} who
showed an increase in H:M ratios of the soleus in similar groups. Differences in our outcomes may be accounted for by the duration of our repeated-measures study design, or the relatively small sample size. It is possible that during this period, the variability in the time for a participant to recover from the injury may have influenced our outcomes. Our results were similar to previous studies investigating differences in lower leg excitability in individuals with functional ankle instability. McVey et al.⁹ suggest that this decrease in excitability in those with functional ankle instability is due to the initial injury with persisting inhibition. Our finding for decreased soleus excitability may further support the hypothesis that differences in H-reflex may lead to the development of Functional Ankle Instability.

At 36 hours post injury, no significant correlation was found between H:M ratios in the TA or SOL and self reported function. These results may suggest that at 36 hours post injury, participants may have progressed past the acute inflammatory phase of healing which is why decreased pain and improved dynamic function may have been reported. Our results may also suggest that spinal reflex excitability does not correlate with the participants’ function at 36 hours post initial injury. Therefore, spinal reflex excitability may not be the only factor influencing a participants function, future research should determine what other measures may correlate with a participants function. On the other hand, our results also showed a significant correlation between H:M ratios of FL and measures of self reported function. Previous studies have shown inhibition of the FL to be strongly linked to FAI.⁴ therefore, it is not surprising that participants with decreased FL spinal reflex excitability would report decreased level of function.
There are limitations to our study that should be addressed. The current study has a small sample size, contributing to insufficient power to observe if differences exist between groups and/or over time. Additionally, participants in our study ranged from recreational to Division I athletes. The standard of care among our participants was not standardized, which may contribute to the degree to which those who suffered an acute lateral ankle sprain were able to recover over time. It is possible that this may have an influence over the outcome of our results. Participants who were collegiate athletes may have showed greater improvements due to high level, consistent care rather than recreational athletes who may not have received the standard of care. As part of an ongoing study, participants were asked to record and describe if they were receiving rehabilitation or treatment for their injury during each test session. Further investigation is needed into whether the level and extent of treatment influence changes seen in measures of motor neuron pool excitability, postural control and self-reported measures of pain and function.

The decrease in spinal reflex excitability of the soleus is similar to those observed in individuals who exhibit functional ankle instability. A potential limitation of this study is that it was unaccounted for whether the participants in the acute LAS group had prior ankle injuries, therefore, it is possible that a number of participants may already have chronic instability that predisposed them to this most current injury, influencing measures of spinal reflex excitability. Future research should include a larger sample size. In this study, we were interested if spinal reflex excitability would correlate with pain and to a subject’s level of function following an acute LAS within 36 hours of injury. We found a significant correlation between function and FL only; however, because spinal reflex
excitability is not the only factor associated with determining function, future studies should consider other factors such as ankle range of motion and girth measurements to quantify swelling. As described earlier, variances in rehabilitation and treatment techniques may have an influence over the outcome of our results. Future research may want to take standardize all treatments and rehabilitation methods.

In conclusion, those who suffer an acute lateral ankle sprain exhibit decreased spinal reflex excitability compared to healthy counterparts within two-weeks of the initial injury. While studies investigating the acute alterations in spinal reflexes of the lower leg muscles are limited, these results should be taken into consideration in ongoing treatment of acute lateral ankle sprains.
References


Appendix A

Tables

Table 1: Demographics

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAS</td>
<td>8</td>
<td>21.00</td>
<td>1.85</td>
</tr>
<tr>
<td>Control</td>
<td>8</td>
<td>20.38</td>
<td>1.60</td>
</tr>
<tr>
<td>Height (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAS</td>
<td>8</td>
<td>174.63</td>
<td>9.77</td>
</tr>
<tr>
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<td>8</td>
<td>173.99</td>
<td>9.21</td>
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<tr>
<td>Mass (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAS</td>
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<tr>
<td>Control</td>
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<td>73.98</td>
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N= number, LAS= Lateral Ankle Sprain

Table 2: Main Effect for Time

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<th>Muscle</th>
<th>DF</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
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<tr>
<td>TA</td>
<td>4</td>
<td>.237</td>
<td>.916</td>
</tr>
<tr>
<td>FL</td>
<td>4</td>
<td>.991</td>
<td>.421</td>
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<td>SOL</td>
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<td>1.293</td>
<td>.285</td>
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</table>

TA= Tibialis Anterior, FL= Fibularis Longus, SOL= Soleus. * denotes significant finding

Table 3: Main Effect for Injured Group

<table>
<thead>
<tr>
<th>Muscle</th>
<th>DF</th>
<th>F</th>
<th>P</th>
<th>Mean</th>
<th>Std Deviation</th>
</tr>
</thead>
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<tr>
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<td>.787</td>
<td>.061</td>
<td>.081</td>
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<td>SOL</td>
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<td>8.70</td>
<td>.011*</td>
<td>.343</td>
<td>.272</td>
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TA= Tibialis Anterior, FL= Fibularis Longus, SOL= Soleus. * denotes significant finding
Table 4: Descriptive Statistics at 36 hours Post-Injury

<table>
<thead>
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<th>Leg</th>
<th>Group</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
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</thead>
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<td>FL</td>
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<td>Function</td>
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<tr>
<td></td>
<td>Global</td>
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Table 5: Correlations

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<th>FADI Sport</th>
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<tr>
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</table>

* denotes significant correlation