2021

Ankle Muscle Activation and Mechanics during the Ebbet's Foot Drills

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ANKLE MUSCLE ACTIVATION AND MECHANICS DURING THE EBBETS' FOOT DRILLS

A thesis submitted to
the Graduate College of
Marshall University
In partial fulfillment of
the requirements for the degree of
Master of Science
In
Exercise Science with a concentration in Athletic
Training
by
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Marshall University
August 2021

APPROVAL OF THESIS

We, the faculty supervising the work of Quentin Adam Archuleta, affirm that the thesis, *Ankle Muscle Activation, and Mechanics during the Ebbets' Foot Drills*, meets the high academic standards for original scholarship and creative work established by the Master of Science and the College of Health Professions. This work also conforms to the editorial standards of our discipline and the Graduate College of Marshall University. With our signatures, we approve the manuscript for publication.

4-27-2021

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ACKNOWLEDGMENTS

First, I would like to thank God for the people he put in my corner and path that helped lead me to the completion of this thesis and my family and friends for believing in me and pushing me to continue my education, and never give up. To Mrs. Crouch, who helped me by reading my whole document and sending me edits. To Coach Depriest, who introduced me to Ebbets' drills and taught me so much about life on and off the course and track. A special thank you to every single participant who completed the study. To my parents, thank you for your love and guidance, and a special thank you to my nanny Rosalind B. Baugh who, without her, my education at Marshall University could not have happened. A final thanks to my committee, Dr. Leigh, Dr. Mcllvain, and Dr. Timmons, for all their help in creating this project and turning it into something attainable during my time here. A special thank you to Dr. Timmons for not giving up on me when things with me got hard.

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ABSTRACT

Introduction:

The ankle is a complex structure of three joints that allow multiplanar motion (Brockett & Chapman, 2016). Lateral ankle sprains (LAS) are the most common injury seen today in both the general and athletic populations and have a high recurrence rate. When left untreated or mistreated, it often leads to developing chronic ankle instability or osteoarthritis, which a lower quality of life. Dr. Russ Ebbets created a set of foot drills with the claim that they can strengthen the muscles of the lower leg, lessen lower leg aliments, and the chances of a severe ankle sprain (Ebbets, 2011a). The purpose of this study was to explore the muscle activation of the lower extremity musculature during Ebbets' foot drills while examining the sEMG of the tibialis anterior, tibialis posterior, peroneus longus, soleus, and during normal walking.

Methods:

Twenty-two college students (11 males, 11 females avg age 23.76) participated in the study with one female being excluded; after informed consent, demographics were collected. Next, the Identification of Functional Ankle Instability questionnaire and the Foot and Ankle Ability Measure questionnaires were taken. After balance testing, preparation of sEMG of the tibialis anterior, tibialis posterior, peroneus longus, and soleus. The sEMG was collected during strength testing and all the walking trials, including normal walking and each Ebbets' foot drill. Mean RMS was calculated for each trial and was used for comparison.

Results:

Results found that compared to normal walking, Ebbets' foot drills increased all the selected muscles' muscle activity compared to normal walking. The tibialis anterior saw a significant increase during all the drills. The tibialis posterior saw a significant increase during the last three

drills. The peroneus longus saw a significant increase during all but one drill. The soleus saw a significant increase during all Ebbets' drills.

Conclusion:

Dr. Ebbets' foot drills have revealed that they generate greater muscle activity than regular walking, which means the drills may strengthen the tibialis anterior, peroneus longus, and tibialis posterior and soleus. These results build evidence on Dr. Ebbets' theory and indicate that these foot drills may be used to rehabilitate and prevent LAS and CAI development.

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CHAPTER 1

INTRODUCTION

When looking at both the general and athletic populations, the most frequent injury to occur in the lower extremity is lateral ankle sprains (Eechaute et al., 2007; Herzog et al., 2019). Lateral ankle sprains are frequent and recurring injuries that can lead to chronic injury and instability (Gribble et al., 2016). Published studies indicate that those who have suffered from lateral ankle sprains (LAS) may have a reinjury rate of up to 73% (Herzog et al., 2019; Yeung et al., 1994). These studies have also reported factors affecting the risk of lateral ankle sprains, such as age, participation in sport, muscle impairment, and other factors that predispose people to injury (Delahunt & Remus, 2019; Fousekis et al., 2012; Kobayashi et al., 2016). Chronic ankle instability (CAI) is a degenerative condition; studies indicate that anywhere from 30 to 70 percent of those who sprained their ankle is likely to develop chronic ankle instability (CAI) (Doherty et al., 2016; Freeman et al., 1965). Chronic ankle instability (CAI) results in chronic pain, ankle instability, and functional impairments (Hertel & Corbett, 2019), with symptoms lasting from one to seven years after the initial injury (Anandacoomarasamy & Barnsley, 2005; Gribble et al., 2016; Konradsen et al., 2002). Annual cost estimates $4.2 billion a year for LAS injuries in the United States in medical expenses (Curtis et al., 2008; Shah et al., 2016; Soboroff et al., 1984). Increased attention to the importance of this injury and the lasting effects should encourage healthcare professionals to understand better the importance of strengthening rehabilitation and prevention (Caldemeyer et al., 2020; Hertel & Corbett, 2019).

Studies report that lack of attention and treatment affects patients later in life (Houston et al., 2014; Hubbard-Turner, 2019; Konradsen et al., 2002). A 2019 study observed 64% of LAS patients did not seek medical attention, had higher re-injury rates, and scored worse on the Foot and Ankle Ability Measure (Hubbard-Turner, 2019). The study highlights that proper care of the initial injury reduced the development of CAI (Hubbard-Turner, 2019). One of the many issues that arise with CAI is the development of osteoarthritis (OA). When investigating OA causes, studies have reported that initial and recurrent LAS often lead to secondary posttraumatic osteoarthritis (Au et al., 2006; Santos et al., 2014; Valderrabano et al., 2006). Multiple studies have indicated functional and mechanical deficiencies in developed CAI people (Benedetti et al., 2012; Delahunt et al., 2006; Kim et al., 2019; Son et al., 2019). Altered ankle movement, biomechanics, neuromuscular control pathways, muscle function, and postural control have all been reported in people with CAI. These impairments interact and negatively impact the patient, outlook on life, and their activities of daily living (Kim et al., 2019; Pietrosimone & Gribble, 2012; Rosen et al., 2019; Son et al., 2019). Untreated and mistreated ankle injuries lead to higher reinjury rates, long-term disability, and functional deficiencies (Hertel & Corbett, 2019; Herzog et al., 2019; Kim et al., 2019; Medina McKeon & Hoch, 2019).

The Ebbets' foot drills are a set of gait exercises created by Dr. Russ Ebbets, who hypothesizes that the drills "eliminate lower leg ailments and lessen the risk and severity of ankle sprains when practiced daily" (Ebbets, 2011a). The Ebbets' foot drills entail walking in non-traditional foot positions for 25 meters each (Ebbets, 2011a). Dr. Ebbets' extensive knowledge and anecdotal experience using the drills when he coached track give support to his claims; "stating that the drills challenge the lower leg muscles by conditioning the muscles creating a clearer neuromuscular pathway from the foot to the brain, giving the body better control of the foot, proprioception, and coordination" (Ebbets, 2011a). However, no empirical research has explored this topic.

Intrinsic and extrinsic muscles of the foot and ankle produce the motion during gait, play a role in the mechanism of injury (MOI), and are affected by injury (Brockett & Chapman, 2016; McKeon et al., 2015; Medina McKeon & Hoch, 2019). Individuals with CAI have shown altered energy distribution and joint stiffness to compensate when jumping, landing, and cutting compared to copers and controls (Kim et al., 2019). The Ebbets' foot drills are used by athletes or active people, although evidence for how they work is minimal. A better understanding of the muscle activity during the drills would support the drills being used to their full potential as a preventative program or used during rehabilitation. Dr. Ebbets hypothesizes that his drills theoretically strengthen and condition the lower leg muscles by walking in various gaits making an abnormal motion normal through practice over time (Ebbets, 2010, 2011a, 2011b), however there is a lack of evidence to support his claims.

Rehabilitating a patient with LAS focuses on reducing functional impairments and disabilities caused by the injury. Lateral ankle sprains typically occur during the foot's transition from non-weight bearing to weight-bearing motions during activity and can be further classified as direct contact, indirect contact (Fong et al., 2009; Safran et al., 1999), and noncontact injuries (Olsen et al., 2004). Regardless of the classification, the mechanism of injury (MOI) is the same, a rapid increase in inversion, with or without plantar flexion, and internal rotation of the ankle/foot complex (Gribble et al., 2016; Medina McKeon & Hoch, 2019; Soboroff et al., 1984). The lower leg muscles control the positioning of the foot and movement of the ankle (Medina McKeon & Hoch, 2019). Weakness or uncoordinated activation of the lower leg muscles may increase the risk of sustaining ankle sprains (Fox et al., 2008; Gribble & Robinson, 2009). Rehabilitating a patient with LAS focuses on reducing functional impairments and disabilities that result from injury. Functional impairments include loss of or decreased range of motion, strength, balance, neuromuscular function, and coordination (Chinn & Hertel, 2010). For example, reduced dorsiflexion is a result and indicator of injury and a predisposition for reinjury if not corrected (Chinn & Hertel, 2010; Terada et al., 2013). In rehabilitation, restoration of dorsiflexion is paramount, substantially impacting most of the normal gait cycle (Chinn & Hertel, 2010). When observing the gait cycle and the lower leg muscle's effects on the ankle during kinematic motion, the dorsiflexors are very active from heel strike through the loading response until the foot is entirely in contact with the floor (DeLisa, 1998). The tibialis anterior reactivates from toe-off through mid-swing (Benedetti et al., 2012; DeLisa, 1998). Impairments in the range of motion and strength will affect the muscle’s ability to properly pull the joint into the correct position, altering gait, kinematics, and function (Kim et al., 2019; Son et al., 2019). If Ebbets’ foot drills used daily can improve impairments that are present from injury, the foot drills could help prevent reinjury or initial injury.

Statement of the Problem

The high prevalence of LAS (Doherty et al., 2014), along with the high rate of re-injury (Yeung et al., 1994), and the risk of developing CAI following a single LAS (Delahunt & Remus, 2019) call for an improved understanding of the methods used to prevent LAS and rehabilitate the patient with LAS is evident. The Ebbets’ foot drills have been described to aid in the prevention and rehabilitation of the LAS (R. Ebbets, personal communication, 2020); however, the muscles of the lower extremity muscle during Ebbets’ foot drills have not been explored. The topic being investigated is how the muscle activity of the tibialis anterior, fibular longus, soleus, and tibialis posterior differ (measured by root means square) between the normal gait cycle and Ebbets’ foot drills. This study's results could provide evidence to support the use of Ebbets’ Foot Drills for the prevention and treatment of LAS. The purpose of the current study was to explore the muscle activation of the lower extremity musculature during Ebbets' foot drills; specifically, the surface electromyography (sEMG) activity of the tibialis anterior and posterior, fibularis (peroneus) longus, and soleus, and was compared to muscle activation during normal gait.

Research Question

Will the activity of the tibialis anterior, fibularis longus, soleus, and posterior tibialis during Ebbets' foot drills differ from the muscle activity during a normal gait?

Null Hypothesis

H_o: Activity measured by mean root means squared (RMS) of the muscles selected of the lower leg (tibialis anterior, fibularis longus, soleus, and posterior tibialis) will not differ amongst Ebbets' foot drills when compared to normal gait.

Alternative Hypothesis

H_1: The tibialis anterior will have a greater mean RMS during Ebbets' foot drills, walking forwards on the heels, on the insides of the feet, toes pointed in, and toes pointed out compared to normal gait.

H_2: The tibialis posterior will have a greater mean RMS during Ebbets' foot drills, walking on the outside of the feet, walking with toes pointed in, walking with toes pointed out, walking on the insides of the feet, and walking backward on the toes compared to normal walking.

H_3: The fibularis (peroneus) longus will have a greater mean RMS during Ebbets' foot drills, walking forwards on your heels, walking toes pointed out, walking on the insides of your feet, and walking backward on your toes compared to normal walking.

Operational Definitions

Alteration: change to system, muscle, or action from its normal or previous function.

Chronic Ankle Instability: a chronic condition defined by recurrent ankle sprains, giving away or the perception of giving away with symptoms of pain, instability, and diminished function (Herzog et al., 2019).

Ebbet's foot drills: a set of walking drills that put the foot in various positions to challenge gait.

Lateral Ankle Sprain: most common lower extremity musculoskeletal injury, acute injury to the lateral ligament complex of the ankle (Medina McKeon & Hoch, 2019).

Electromyography: a tool that lets us record a muscle's action potential and recruitment of motor units (Hermens et al., 2000).

Muscular activity: the quantifiable data from electromyography analysis, i.e., max, min, RMS mean.

Osteoarthritis: arthritis that affects bones' ends where joints form (Song et al., 2019).

Posttraumatic osteoarthritis: results from acute or recurrent traumatic joint injury (Brown et al., 2006).

Limitations

The limitations of this study include:

1. Participants familiarity with the required motions of doing the Ebbets' foot drills one time.
2. Variability among participants' natural aptitude to perform the Ebbets' foot drills one time.
3. Participants were collected from a convenience sample.
4. Patients did not wear shoes for any of the drills.

5. No post-strength testing was done.
6. A single person was excluded from the study due to having pains 2 > 10 during strength testing.

Delimitations

The delimitations for this study include:

1. The participants are 18 to 30 years old.
2. The participants have a healthy foot and ankle.
3. The participants are not collegiate, professional, or varsity sport athletes.
4. Participants did not have chronic ankle instability.

Assumptions

The assumptions for this study are included:

1. The Ebbets' foot drills theoretically strengthen and condition the muscles of the lower leg and ankle by strengthening them, creating endurance and better dynamic stability, preventing sudden collapses or unwanted moments of inversion or eversion, and better control dorsiflexion and plantar flexion by walking in various gaits making an abnormal motion normal through practice over time (Ebbets, 2010, 2011a, 2011b).
2. Walking forwards on the heels should focus on the tibialis anterior and the fibularis longus.
3. Walking on the outside of the foot should work on fibularis longus, tibialis anterior, and posterior tibialis.
4. Walking on the inside should work on the fibularis longus, anterior tibialis, and posterior tibialis.

5. Walking on the toes while the feet are pointed out should work on the fibularis longus, posterior tibialis, and soleus.
6. Walking on the toes while the feet are pointed in should work the posterior tibialis and soleus.
7. Walking backward on the toes should work the tibialis posterior, fibularis longus, and soleus.
8. All within-subject measurements will have a normal distribution.
9. Participants gave maximal effort during strength testing.

CHAPTER 2

LITERATURE REVIEW

Introduction

The purpose of the current study was to explore the activation of the selected lower extremity musculature, the tibialis anterior, tibialis posterior, peroneus (fibularis) longus, and soleus, during Ebbets' foot drills. The muscles' weakness can lead to less efficient biomechanics and stability. For example, the tibialis anterior muscle weakness would lead to less dorsiflexion or foot clearance during gait and a less controlled plantarflexion or foot flopping (Canavese & Deslandes, 2015; Prentice, 2017). The foot and ankle have been proposed to have a core system like the lumbo-hip-pelvic complex system (McKeon et al., 2015). The foot and ankle core system is divided into three parts, passive, active, and neural (McKeon et al., 2015). Ligaments and bones make up the passive system (McKeon et al., 2015). Muscles make up the active system, and nerves and receptors make up the neural system (McKeon et al., 2015). Injury may alter the foot and ankle's core system, creating instability and alterations, resulting in injury or re-injury of the ankle (Gribble, 2019; Gribble et al., 2016). This study was focused on the active system of the ankle core theory, which is the ankle's musculature, and how activity and control of musculature affect the control of the foot and ankle during gait and Ebbets' foot drills.

This literature review will inform the reader about basic ankle anatomy, ankle kinematics, and functions during the gait cycle. Its intended purpose is to review the injury of lateral ankle sprains and the utilization of surface electromyography (sEMG) as a tool to uncover the deficits seen with ankle injuries. Further evaluation of alternative assessment tools such as force, kinematics, muscle excitability, and gait show that lateral ankle sprains (LAS) and its development into chronic ankle instability (CAI) negatively affect the function of the ankle joint beyond the active system. The literature goes on to emphasize the prevalence of LAS and its associated risks to sustaining an injury. The incidence of reoccurrence due to lack of medical treatment and its correlation with further damage is indicative of the more severe and lasting consequences of ankle injuries such as chronic ankle instability and post traumatic osteoarthritis.

Ankle Anatomy

Overview.

The foot and ankle make up the most distal part of the lower leg. The foot and ankle are 26 individual bones that conjoin with the two larger leg bones, the tibia and fibula (Brockett & Chapman, 2016; Ebbets, 2010; Prentice, 2017). The bones in the ankle and foot break down into 14 phalangeal bones, seven tarsal bones, five metatarsal bones, two sesamoid bones, and the leg's two long bones (Brockett & Chapman, 2016; Prentice, 2017). The ankle may be mistaken for just one joint but is multiple joints that work in synchrony to create the optimal movement of the ankle and its interaction with the ground so people can fulfill their activities of daily living (Brockett & Chapman, 2016). A complex structure of the three joints (subtalar, talocrural, and tibiofibular) forms the ankle joint, allowing the ankle's three-dimensional motion (Hertel, 2002). Thirteen muscles act on the ankle to produce the ankle's motion (Brockett & Chapman, 2016). The bones, joints, and muscles all come together to create this complex joint and its function.

Joints.

The subtalar joint is formed by the inferior surface of the talus and the superior surface of the calcaneus, and the motions at this joint are pronation and supination (Hertel, 2002; Medina McKeon & Hoch, 2019). The subtalar joint functions almost like a ball and socket joint, with the talus being the ball and the calcaneus being the socket (Hertel, 2002). The literature describes variability in the names and functions of the subtalar joint's ligamentous structure (Hertel, 2002).

Still, researchers after 2002 agree with Hertel et al. (2002), who describes and groups the ligaments of the subtalar joint into the deep, the peripheral, and the retinacula ligaments (Hertel, 2002; Medina McKeon & Hoch, 2019). The subtalar joint's ligaments resist and stabilize supination, pronation, inversion, internal rotation, and support the lateral joint (Hertel, 2002; Medina McKeon & Hoch, 2019). These ligaments stabilize and constrain the subtalar joint so it can withstand the stresses of activities of daily living.

The talocrural or tibiotalar joint, is formed by the talus's dome, the malleoli of the tibia, and fibular malleoli, is a hinge joint, and the motions at this joint are dorsiflexion and plantar flexion (Hertel, 2002). The tibia and fibula come together and sit on top of the talus; a visual reference could be of a cowboy's saddle on a horse, connections of the saddle on the horse are on all sides. Ligaments support this joint on the lateral and medial sides (Hertel, 2002). The lateral ligaments resist and stabilize inversion, internal rotation and lessen valgus forces, while the deltoid ligaments resist and stabilize eversion and reduce varus forces (Brockett & Chapman, 2016). All the ligaments provide dynamic and static stability to the talocrural joint to withstand stresses and prevent an excessive range of motion.

The tibia and fibula's interaction forms the tibiofibular joint, sometimes called the ankle syndesmosis (Medina McKeon & Hoch, 2019). A visual reference mentioned earlier would be the saddle on the horse, where the tibia and fibula create the saddle. While the tibiofibular joint is seen as a part of the talocrural joint, the joint has its articulations and functions like a joint, providing more stabilization and less motion (Brockett & Chapman, 2016; Hertel, 2002). While stabilization is the primary role of the tibiofibular joint, accessory gliding with the talocrural joint is vital for the ankle's proper function (Hertel, 2002). The thick interosseous membrane gives the joint high structural integrity with help from the anterior tibiofibular ligament and the posterior tibiofibular ligament (Brockett & Chapman, 2016).

These three joints and their ligament support create the ankle joint complex's foundation, which works synergistically to create the ankle's movements and function (Prentice, 2017). In the ankle complex in the core system theory, the joints and ligaments would be the passive system (McKeon et al., 2015). The passive system is vital to our study because, without proper structural integrity of the joints' foundation, there would be improper function and motion of the joints affecting gait and activities of daily living (McKeon et al., 2015). For example, if there is an injury, the passive system is now changed. Other systems such as the active system (muscles) may have to work harder to continue to allow gait and daily living activities. A change in the foundation will change the whole system.

Motions.

The extrinsic muscles originate at the lower leg and insert on the foot. The foot and ankle's extrinsic musculature produces the motions, dorsiflexion, plantarflexion, inversion, eversion, abduction, adduction, supination, and pronation around the ankle (Medina McKeon & Hoch, 2019). The intrinsic muscles originate and insert on the foot. The intrinsic muscles control the foot and toe flexion movements, toe extension, toe and foot abduction, toe and foot adduction, foot pronation, and foot supination (Prentice, 2017). Contracting extrinsic muscles create dynamic protection of the ankle joints and provide dynamic stability. This dynamic stability helps protect against the inversion, plantar flexion, and internal rotation injury mechanism of LAS. When looking at the muscles, the concentric and eccentric functions need consideration because of their dynamic stability and control roles (Hertel, 2002).

The extrinsic muscles work synergistically at the ankle joints to create the ankle's movements (Brockett & Chapman, 2016; Hertel, 2002; Medina McKeon & Hoch, 2019). These four motions at the ankle are dorsiflexion, plantar flexion, inversion, and eversion (Brockett & Chapman, 2016). Dorsiflexion occurs at the talocrural joint and can be explained as pulling the toes to the sky (Medina McKeon & Hoch, 2019). Plantarflexion occurs at the talocrural joint and can be explained by pointing the toes to the floor (Prentice, 2017). Inversion and eversion occur at the subtalar joint (Maceira & Monteagudo, 2015). Inversion can be interpreted as trying to point the toes to the opposite knee. Eversion can be explained as trying to point the toes to someone's knee, sitting next to you. Supination and pronation occur at the forefoot and represent a combination of motions seen at the forefoot and ankle (Maceira & Monteagudo, 2015). Supination is a combination of inversion and adduction, and pronation is a combination of eversion and abduction. It can be explained as trying to touch the lateral edge of the foot to the floor (Maceira & Monteagudo, 2015). Pronation combines eversion and abduction and can be described as trying to touch the foot's medial edge to the floor (Maceira & Monteagudo, 2015). These are the motions seen throughout the ankle complex, and the muscles work together around the joints to perform these motions. The structural integrity of the joints and function of the muscles is pertinent to creating regular and fluid motions seen at the ankle (Brockett & Chapman, 2016).

Muscles.

The foot and ankle's extrinsic muscles can be divided into the anterior, lateral, superficial posterior, and deep posterior compartments (Hertel, 2002). Each compartment's muscles contribute to motion and stability for each movement seen at the ankle (Medina McKeon & Hoch, 2019). Looking back at the ankle core system, the muscles are active (McKeon et al., 2015). The active system's proper function is paramount for ideal foot positioning during gait, control of that positioning, and movement to best protect and optimize function during activity (Hertel, 2002; McKeon et al., 2015).

Specific interest to the mechanism of LAS is the tibialis anterior (TA) apart of the anterior compartment, the fibularis longus (FL) apart of the lateral compartment, and the posterior tibialis (PT) apart deep posterior compartment. The primary motion performed by the tibialis anterior is dorsiflexion, but eccentrically, the muscle controls the lowering of the foot to the ground during walking and running (Brockett & Chapman, 2016; Medina McKeon & Hoch, 2019). The primary motion performed by the fibularis (peroneus) longus is eversion, but it also assists with plantarflexion; eccentrically; the muscle stabilizes supination of the ankle during activity and is essential for protection against lateral ankle sprains (Brockett & Chapman, 2016; Medina McKeon & Hoch, 2019). The soleus (SL) 's primary motion apart from the superficial posterior compartment is plantarflexion; however, eccentrically, the soleus controls tibial progression over the ankle and foot during walking and running (Brockett & Chapman, 2016; Medina McKeon & Hoch, 2019). The tibialis posterior primary motions are inversion and plantar flexion (Semple et al., 2009); eccentrically, the muscle controls pronation during walking and running (Ivo Waerlop, 2016; Semple et al., 2009).

The muscles are the active system that controls the ankle's motion and stabilization during running and walking. The active system also directly interacts with the neural system to optimize function from when input is received to muscle action (McKeon et al., 2015). The tibialis anterior, peroneus (fibularis) longus, soleus, and tibialis posterior muscles were selected for this study because of their influence in their anatomical compartments, i.e., being the main action of movement, the alterations in these muscles seen in electromyography (EMG) studies that focused on the ankle that included population with and without injury, Ebbets' foot drills and their reasoning (Medina McKeon & Hoch, 2019) (Ebbets, 2010, 2011a, 2011b; Medina McKeon & Hoch, 2019). The muscles' ideal function is crucial for creating required motions, stabilization, and ankle joints' protection during day-to-day activities and gait.

Ankle Kinematics During the Gait Cycle

The ankle complex can be argued as the most important component of the lower kinetic chain during motion because of its direct interaction and exchange of forces with the foot. In contrast, the foot interacts with the ground. Optimal kinematics, positioning, and muscle actions create normal biomechanics when walking and running (Delisa, 1998). The following will explain the gait cycle and kinematics seen at the foot and ankle.

***Gait cycle*.**

The gait cycle can be defined as a recognized pattern of motion from the limb segments and joints that results in walking or running and is an interval starting and finishing with the same foot (DeLisa, 1998). The gait cycle can be divided into two major parts: the stance phase and the swing phase. Each of the two phases is broken down further. In walking gait, while one leg is in the stance phase, the other leg is in the swing phase. When discussing the stance or swing phase, it is frequently presented in a percentage of the whole cycle (Magee, 2014).

The stance phase makes up 60% of the gait cycle and can be divided into five parts, heel strike, loading response, midstance, terminal stance, and pre-swing (Delisa, 1998). The stance phase has two main functions: absorption and propulsion (Prentice, 2017); during absorption (heel strike, loading response, midstance), the muscles work eccentrically, and during propulsion (terminal stance and -pre-swing), they work concentrically (Perry et al., 2010; Whittle, 2007). For example, when inversion occurs at heel strike, the evertors will work eccentrically to help control inversion and resist Hyperinversion. During the stance phase, switching between the double and single leg supports is seen (Delisa, 1998 ; Magee, 2014). During midstance and terminal stance, the body is supported by a single leg, while initial contact and the early parts of the loading phase are supported by both legs (Perry et al., 2010; Whittle, 2007). During the stance phase in the sagittal plane, the ankle motions are plantarflexion, dorsiflexion, and plantar flexion (Au et al., 2006). In the frontal plane, inversion of the foot starts at heel strike (Nordin & Frankel, 2012). Multiplanar motions are also seen; pronation occurs at heel strike to help with absorption, and supination occurs at toe-off to help propulsion (Nordin & Frankel, 2012).

The swing phase makes up the other 40% of the gait cycle and is from -toe-off to the next heel strike (DeLisa, 1998). This phase can be divided into three parts: initial swing, midswing, and terminal swing, and are known for their functions; initial swing being acceleration and terminal swing being deceleration (DeLisa, 1998). Acceleration occurs as the foot is lifted off the floor and forward (Delisa, 1998 ; Magee, 2014). Deceleration occurs as the foot and leg prepare for contact with the floor (Delisa, 1998 ; Magee, 2014).

The gait cycle is intricate, having many parts come together all to create motion. Accurate interactions and command of the joints, ligaments, muscles are critical in creating a normal gait. Any injury to either part will alter these complex interactions and affect normal gait. The optimal gait cycle is vital to our study because normal gait is our baseline to compare the drills, and if the hypothesis is proven correct may add scientific backing to Dr. Ebbets' theory for the foot drills and their use.

Kinematics.

Kinematics is the study of the body's motion without looking at the internal and external forces that cause the movement and can be used to describe the gait cycle (Enoka, 2002). Tying this to the ankle core system, kinematics looks at the passive system's motion, which is the bones, joints, and ligaments (McKeon et al., 2015). The foot and ankle have two critical roles of the lower kinetic chain. The first is the foot directly interacts with the ground. The second is the foot and ankle relationship and their interactions with the rest of the lower kinetic chain.

During optimal gait in the stance phase, the foot and ankle complex create a wheel rocker type of motion, and three rocker motions are seen, the heel rocker, ankle rocker, and forefoot rocker (Canavese & Deslandes, 2015). The heel rocker's role is for deceleration and progression, the ankle rocker is for stabilization and progression, and the forefoot rock is for support (Canavese & Deslandes, 2015). These rockers help control the foot and ankle as they go through the stance and help prepare them for the swing phase (Canavese & Deslandes, 2015).

During the swing phase, there are no rocker-type motions, but the foot and ankle are in various positions. Initial swing, the ankle is in plantar flexion, and the foot is behind the body (Canavese & Deslandes, 2015). Midswing the ankle is in dorsiflexion to help foot clearance (Canavese & Deslandes, 2015). In terminal swing, we see the ankle in neutral positions to prepare for initial contact (heel strike) of the stance phase (Canavese & Deslandes, 2015).

When a LAS occurs, the MOI is a rapid increase in inversion and internal rotation with or without plantarflexion; External rotation of the medial foot column can also be seen with the clinical MOI (Medina McKeon & Hoch, 2019). So kinematically, during the first two rockers (heel rocker, ankle rocker) of the stance phase is when an injury may occur. Having control and stability during these motions is crucial to preventing LAS.

The body’s positioning during motion is essential to carry out a normal gait. Improper positioning or lack of motion will affect the overall motion during gait and predispose someone to injury (Chinn & Hertel, 2010).

The gait cycle and kinematics come together to give optimal foot and ankle movements during walking, running, and other activities. Alterations to the system and the interactions of the anatomic structures can change the ankle's function, predisposing a person to injury and change the person's gait, which may lead to further injury. The gait cycle and kinematics are pertinent to this study. If Ebbets' foot drills can work in a preventative manner, then the prescribed daily use of these drills could help lessen injury chances. If Ebbets' foot drills can work in a rehabilitative setting, maybe there could be a reversal of some of the alterations seen in gait and kinematics due to injury.

Mechanism of Injury and Injury Types

The mechanism of injury (MOI) is how an injury typically occurs. Lateral ankle sprains usually occur during the foot's transition from non-weight bearing to weight bearing motions during activity (Fong et al., 2007). They can be further classified as direct contact, indirect contact (Fong et al., 2009; Safran et al., 1999), and noncontact (Olsen et al., 2004). Direct contact involves contact from another player to the medial leg just before or during foot placement, resulting in forced inversion; an example of this in soccer is when a tackle is made to another player who is dribbling the ball (Fong et al., 2009). Indirect contact involves contact from an obstacle or individual that changes the way the foot is placed during landing; an example of indirect MOI is when a basketball player or volleyball player is landing and steps on someone else's foot, or when a cross country runner lands in a hole on the trail (Safran et al., 1999). Noncontact injuries involved landing inappropriately when no other external forces or obstacles are involved; an example would be when a volleyball player comes down from a block and just does not land right and entices an injury (Olsen et al., 2004). Indirect and noncontact injuries typically occur during activities that demand high agility and cutting (Medina McKeon & Hoch, 2019). Examples of high agility and cutting sports would be sports such as basketball and soccer.

No matter the type, the MOI is a rapid increase in inversion and internal rotation with or without plantarflexion; External rotation of the medial foot column can also be seen with the clinical MOI (Medina McKeon & Hoch, 2019). With the MOI, the primary damage is to the lateral ligaments. Damage to them is graded from grade I to grade III, grade I being some stretching, to grade III, which is the complete tearing of the ligaments (Chinn & Hertel, 2010). Ligament damage is not the only structural damage that can occur with LAS; osteochondral lesions, tendon strains, and retinacula lesions may also occur (Hertel & Corbett, 2019). Ebbets' foot drills challenge normal gait by making abnormal motions normal with practice. Walking with toes in pointed almost puts the body in a high-risk MOI position (plantarflexion & inversion) for a LAS. However, using balance, strength, and proprioception with each step ensures there is no unwanted collapse during the gait. If Ebbets' foot drills, in a sense, prepare the body for MOI moments during activity, this could back the theory of the drill's preventative capabilities and their use for rehabilitation.

Muscle Activation

Electromyography is a tool that lets us observe the activity of muscles by analyzing the electrical activity of those muscles (Enoka, 2002). For this study, the tibialis anterior, peroneus (fibularis) longus, soleus, and posterior tibialis were selected for their roles in motion (one muscle for each direction) of the foot and ankle and the changes seen with injury.

***Tibialis anterior*.**

The tibialis anterior (TA) is primarily a dorsiflexor but assists with inversion (Prentice, 2017). The literature reviewed has shown various alterations of the anterior tibialis function during tasks of daily living and activity such as walking, jumping, and landing and changing from double to single leg stances between normal, CAI, and acute LAS (Bavdek et al., 2018; Dingenen et al., 2015; Doherty et al., 2015; Feger et al., 2015; Son et al., 2019). When walking, the tibialis anterior had less muscle activation during the early stance, more activity during the pre-swing phase, and had earlier onset times (statistically insignificant) in the CAI group (Feger et al., 2015; Son et al., 2019). These findings were attributed to maladaptations in biomechanics and feedforward mechanism, where the body plans to complete a task with or without injury (Feger et al., 2015; Son et al., 2019). These maladaptations seem to be the body's response for protection but may increase reinjury susceptibility (Son et al., 2019). The muscles' pre-activation may be a version of the feedforward mechanism (Delahunt et al., 2006).

When walking on the 30° degree angled ramp walking with the entire foot and just the lateral edge touching (medial edge of the foot), the tibialis anterior showed more muscle activity than normal walking in the healthy group (Bavdek et al., 2018). The authors attributed this increase in activity to stability and the stretch reflex (Bavdek et al., 2018). The increase of muscle activity for stability prevented the ankle from collapsing, and the stretch reflex was seen because the inclined ramp stretched the peroneus longus (Bavdek et al., 2018).

When completing the task to go from double-leg to single-leg stance in shoes, with and without orthotics or barefoot, the tibialis anterior showed in the CAI group to have faster onset times in shoes with custom orthotics than barefoot (Dingenen et al., 2015). These results were contributed to preparatory muscle activation, which is the body compensating for electromechanical and reflex delays, which sounds very similar to the feedforward mechanism (Dingenen et al., 2015; Feger et al., 2015). The second reason being sensory reweighting theory, which is the body relying on its sensory information. Wearing shoes seems to give the mechanoreceptors more contact surface, making the information more efficient (Dingenen et al., 2015). The literature has shown that the anterior tibialis function and activity differs from the healthy person to the CAI person. While the changes seem to be a protective response, reinjury is still a high occurrence, and therefore these maladaptations are not beneficial in the long term.

The tibialis anterior has shown varying muscle activity in participants with CAI and compared to a healthy group; so, when is it good and when is it bad? The literature indicates that increase muscle activity in the CAI group compared to healthy control is bad due to the greater rate of muscle fatigue during gait (Feger et al., 2015). Muscle weakness leads to higher recruitment of muscles and faster muscle fatigue, leading the body to alter gait to complete the task still; for instance, landing in a more closed pack position or relying on the proximal leg for more stability (Kim et al., 2019). It is also bad when muscle activity is less compared to healthy control because there are electromechanical delays where the body may not be acting fast enough from the information given and not putting the foot in the most optimal position at the right time (Dingenen et al., 2015). When greater muscle activation is beneficial seems is when healthy participants can generate greater muscle activity. An example of great muscle activation would be when walking on the inclined ramp, which can strengthen and condition the muscles (Bavdek et al., 2018). While Ebbets' foot drills may not be on an inclined ramp, they are similar positions and could produce similar results, and this is what we intend to reveal with this study with the tibialis anterior.

Fibularis longus.

The fibularis (peroneus) longus (FL or PL) is an evertor but also helps plantarflexion of the foot (Brockett & Chapman, 2016; Medina McKeon & Hoch, 2019). The literature reviewed has shown various alterations of the fibularis in its function after injury or in people with CAI compared to people without CAI during tasks such as walking, jumping, and landing and changing from a double to single leg stances (Bavdek et al., 2018; Delahunt et al., 2006; Feger et al., 2015; Son et al., 2019; Webster et al., 2016).

During barefoot walking, the peroneus longus in the CAI group showed an increased activity from heel strike to after heel strike (Delahunt et al., 2006). The reason discussed for these alterations seen was a feedforward mechanism (Delahunt et al., 2006). The feedforward mechanism is the body's ability to plan out functional tasks at hand (Delahunt et al., 2006). During walking, the peroneus longus in the CAI groups showed less activity during early stance and midstance but with earlier onset times and longer activation (Feger et al., 2015; Son et al., 2019). Less peroneus longus muscle activity was explained by altered biomechanics, which could lead to less dynamic stability and altering optimal foot positioning during the stance phase (Son et al., 2019). Earlier onset times and increased time of activation during gait were explained by feedforward motor control in an attempt to protect the joint but may hinder the dynamic stability (Feger et al., 2015; Son et al., 2019).

When jumping and landing post fatigue, the fibularis longus showed higher muscle activity in the CAI group than in the control (Webster et al., 2016). This higher muscle activity was contributed to the feedforward mechanism, explaining that the increase in activity was the CAI patients trying to protect their ankles from unwanted movement or a sudden collapse when landing (Webster et al., 2016).

Healthy participants with stable ankles showed greater muscle activity when walking on an angled ramp with the full and lateral edge of the foot touching compared to normal walking on a flat surface (Bavdek et al., 2018). Greater muscle activity was explained as the muscles working harder to prevent collapsing from walking on the inclined ramp and give stability during the challenging gait task (Bavdek et al., 2018). The amount of muscle activation is an essential factor during gait; less than optimal can create alterations in gait and unstable positionings. With Ebbets' drills being a set of challenging gait tasks, in this study, it is expected to see more muscle activity compared to normal walking, as seen in the Bavdek et al. 2018 study.

Timing of muscle activation is crucial in gait; too early or late can cause asynchronous activity or lead to premature fatigue of the muscles or lead to less control of the foot and ankle positioning (Feger et al., 2015; Son et al., 2019). When transitioning from double-leg to single-leg stance in shoes with and without orthotics or barefoot, the fibularis longus in the CAI group showed earlier onset times in standard shoe only and shoes with orthotics compared to barefoot (Dingenen et al., 2015). The reason discussed for these results was because of preparatory muscle activation and the sensory reweighting theory (Dingenen et al., 2015). Preparatory muscle activation is a way the body can compensate for electromechanical delays and reflexes by having early muscle activation, which sounds very similar to the feedforward mechanism, where the body plans to complete a task with or without injury (Dingenen et al., 2015). The sensory reweighting theory is the reliance on the sensory inputs in the body that provide the most functional and reliable information; for instance wearing shoes gives more surface contact to the feet, which may increase the reliability of the information from the foot and ankle (Dingenen et al., 2015). The sensory reweighting theory, I believe, is what Dr. Ebbets wrote about when presenting his foot drills, discussing creating a clearing pathway from the foot to the brain, working and relying on the cutaneous mechanoreceptors on the plantar surface of the foot while putting the foot in those various gait positions and creating a more efficient pathway.

Studies have shown that the peroneus longus function and activity changes from the healthy person to the CAI person. The changes seem to be a protective response but come with high fatigability and less stability, creating a susceptible gait, which may be why people with CAI feel a giving away and have episodes of giving away since less dynamic stability and control from the protective response. Ebbets' foot drills walk on the lateral part of the foot, just like the Bavdek et al., 2018 study, and hopefully, the same positive effect will be seen.

Soleus.

The soleus (SL) is a plantar flexor (Brockett & Chapman, 2016; Medina McKeon & Hoch, 2019). The purpose of the soleus in our study is to see its activity during these drills and give a check and balance to our posterior tibialis sEMG to confirm the collection of valid signals. The literature reviewed has not shown many alterations of the soleus during tasks of daily living but has given some information on its possible roles in stability.

When barefoot walking, the soleus showed similar results in the CAI group and control group, and it could be said that the soleus was not affected (Delahunt et al., 2006). However, when healthy participants walked on the angled ramp, the soleus was the most active of all the plantar flexors recorded in all three walks (Bavdek et al., 2018). While the direct results were not given for the soleus, they were discussed as the most active. The gastrocnemius results had higher activity during the full foot and lateral edge touching when walking compared to normal walking. So if the soleus had the highest activity, then it can be assumed the soleus had higher activity during full foot and lateral edge walking (Bavdek et al., 2018). Walking on the inclined ramp challenges gait, and the soleus may be recruited for stability when walking on the inclined ramp. Ebbets' foot drills place the foot in challenging positions, and one particularly like the walking on the incline ramp seen in the Bavdek study is walking on the outside of the feet; hopefully, the research being conducted will expand on the soleus stability role during challenge gait positions such as Ebbets' foot drills and give us a significant check and balance to our posterior tibialis EMG.

Posterior tibialis.

The posterior tibialis mainly does inversion and assists with plantarflexion (Ivo Waerlop, 2016; Semple et al., 2009). The literature reviewed has not shown the tibialis posterior in CAI participants during tasks such as walking, jumping, landing, and changing to double and single-leg stances. This may be because of the difficulty of sEMG or the invasiveness of collecting intramuscular EMG for the posterior tibialis and being overlooked as a muscle affected in the ankle. However, there are studies on the alterations of the posterior tibialis activity in other diseases and injuries.

Posterior tibial tendon dysfunction (PTTD) usually starts as paratenonitis, inflammation of the sheath covering the tendon, and can progress to the tendon tearing and is the most common cause of adult acquired flatfoot deformity (Ringleb et al., 2007). When assessing gait in people with acute PTTD vs. healthy control, EMG activity differences of the muscle were found (Ringleb et al., 2007). During the second half of the stance phase, the peak EMG of the posterior tibialis was significantly greater in the PTTD group. The investigators contributed to this increased muscle activity of the posterior tibialis working harder to support the foot's arch (Ringleb et al., 2007). Ebbets' foot drills claim to focus on the strengthening and conditioning of the posterior tibialis, which, if proven to be accurate, would help fix or maintain the arch and the function of the posterior tibialis during gait (Ebbets, 2011b).

Rheumatoid arthritis (RA) is a chronic condition that affects the feet, joints, and soft tissues (Grondal et al., 2008). This condition can be accompanied by additional problems such as acquired flatfoot (pes plano valgus) and tibialis posterior tenosynovitis (Barn et al., 2013).

Differences in EMG activity of the posterior tibialis were found when looking at gait in people with tibialis posterior tenosynovitis with associated pes plano valgus in rheumatoid arthritis vs. healthy control (Barn et al., 2013). Compared to the control, the RA group had higher EMG activity in the posterior tibialis, and earlier onset times during the stance phase (Barn et al., 2013). The investigators contributed to the higher activity and earlier onset times to keep the foot's stability, working harder to maintain the foot arches' integrity even though they saw midfoot collapse during gait (Barn et al., 2013). The collapse could be due to the posterior tibialis' weakness, weakness of the posterior tibialis muscle decreased the arch's structural integrity, which can lead to midfoot collapse. Suppose Ebbets' foot drills have truth in the claims of strengthening the muscles and the posterior tibialis. In that case, there could be a reverse of the arch collapse or minimize it if used in rehabilitation.

EMG has been proven to be a valid and reliable tool for assessing musculature activity during gait and various activities. These studies have shown that EMG is the best tool to answer our question, what are these muscles doing during Ebbets' foot drills? Ebbets' foot drills seem to follow the sensory reweighting theory. The theory is that the body is using the sensory information provided is the most functional and reliable (Dingenen et al., 2015). In the Dingenen et al. 2015 study, increased muscle activity was identified with wearing shoes, saying the shoes increased surface contact of the foot's plantar mechanoreceptors, thus increasing the clarity of the sensory information provided (Dingenen et al., 2015). What Ebbets' foot drills seem to work along with this same theory by putting the foot in these various positions, increasing unused contact surface with the ground to increase the quality of the sensory information provided, i.e., walking on the inside and outsides of the feet. Dr. Ebbets claimed that these drills could be used to strengthen the neural pathway between the brain and foot after training. After using the

Ebbets' foot drills, these pathways should become more efficient. This study hopes to see an increase of muscular activity recorded by EMG during Ebbets' foot drills to prove these drills can isolate, strengthen, and condition the muscles.

Besides musculature activity, other measurements of alterations in CAI and acute LAS have been recorded, such as kinematics, ground reaction forces, joint angle, joint moment, joint stiffness, torque, muscle excitability and could contribute or be a product of the musculature deficits such as strength and activation time (Kobayashi et al., 2016). For example, poor balance can result from suboptimal muscle function.

Alterations have been recorded from initial injury to CAI, and the changes seen in the acute LAS had the same patterns as what was seen in the chronic ankle instability group (Doherty et al., 2015). While these studies did not directly look at the activity of the muscles, they are tied together. The same CAI population has shown muscle weakness, muscle onset time changes, and activation changes (Delahunt et al., 2006; Feger et al., 2015; Son et al., 2019). That same population shows these modified gait patterns, weight distribution, and resting muscle threshold (Flevas et al., 2017; Kim et al., 2019; Rosen et al., 2019; Son et al., 2019). Ebbets' foot drills aim to isolate the muscles, strengthen and condition them, and create better neuromuscular control (Ebbets, 2011a). If proven true, then some of the impairments and altered gait in people with CAI or acute LAS showing the same trends could be stopped, minimized, or reversed.

Prevalence of Lateral Ankle Sprains

Ankle sprains are the number one lower extremity injury seen today, whether it be elite athletes, recreational athletes, or the physically active in the general public (Gribble et al., 2016). For all the information collected and published for lateral ankle sprains, the prevalence of LAS has been calculated for various people and groups. For this study, prevalence was broken down into general and athletic populations.

For the athletic and active population, various studies have been published for prevalence. Athletes of all calibers put demands on the body that most nonactive people usually will not experience. When reporting on sports at various levels worldwide, the ankle was the most prevalent location of injury 34% (24 sports) reported, and 76% of injuries were lateral ankle sprains(Fong et al., 2007). The sports which reported the highest incidence were soccer and basketball (Fong et al., 2007). A study on all types of ankle sprains found lateral ankle sprains the highest at 0.93/1000 AE (One athlete participating in one game or practice) of all types of ankle sprains (Doherty et al., 2014). These studies show that lateral ankle sprains are most prevalent, and certain sports are at a higher risk. When surveying different athletic levels and the prevalence of LAS, it was found that of all the sprains documented, 73% (414) were recurrent sprains: happening at least twice, with 22% of them being five sprains or more (Yeung et al., 1994). The authors noted no significant difference in the rate of occurrence between athleticism levels, but they all followed the same trend, reporting most of the ankle sprains in the at least two sprains bracket (Yeung et al., 1994). Another study looking at high school and college athletes found overall LAS prevalence were similar, but college athletes had a higher athletic exposure incidence (Hootman et al., 2007; Swenson et al., 2013). This helps reinforce similar occurrences between levels of athletic activity. These studies show that recurrent ankle sprains are prevalent among all levels of competition.

The general population may not be elite professional athletes, but they can still experience lateral ankle sprains in activities of daily living. A study in the U.S assessed the prevalence of LAS in the general population calculated an incidence of 2.15 per 1000 person years (how many injuries seen if you followed 1000 people for a year) (Waterman et al., 2010). This study confirms that not just the athletic and competitive population is affected by lateral ankle sprains, but the general population also suffers. Two other studies reported similar prevalence rates (Gribble et al., 2016; Kemler et al., 2015). The overall low prevalence rates were because of two things: first, less physical demands than a sport or a high physical job, and second, people tend not to seek medical attention for a LAS. Confirming the thought people do not seek medical attention for LAS, a study sent surveys out assessing ankle sprains that were and were not treated in the E.R, and the overall incidence rate of 19-26/1000 person years was calculated (Kemler et al., 2015). Then, looking at those who went to the E.R., the incidence rate was 2.15 to 3.29/1000. This helps confirm people do not seek medical care and confirm that the general population prevalence has been reported low (Gribble et al., 2016; Kemler et al., 2015; Waterman et al., 2010). These studies confirm ankle injuries are a problem in the general population that may be more serious than previously thought because of underestimation due to lack of treatment sought.

Ankle sprains are the number one lower extremity injury seen today, whether it be elite athletes, recreational athletes, or the physically active general public (Gribble et al., 2016). From the prevalence information provided, risks have been calculated to help the understanding of LAS. While many intrinsic and few extrinsic factors are present, the information provided helps give insight into the vast information about ankle sprains (Delahunt & Remus, 2019). Intrinsic risk factors are inside the body, such as the history of injury, muscle strength, muscle timing, muscle imbalance, and proprioception. All could stem from muscle dysfunction that was maladapted from the initial injury or during the development of CAI (Delahunt & Remus, 2019). Extrinsic risk factors are outside of the body, such as sports participation; the person chooses the sport but not its demands (Delahunt & Remus, 2019). It has been shown that lateral ankle sprains are a common injury and have been documented for the past 35 years. Lateral ankle sprains occur in all populations, athletic and general. The general population's studies have found a lower end prevalence, but this comes with conflict because this may be an underestimation since people do not always seek medical attention for ankle sprains. In the athletic population, we see higher incidence rates than the general population. The most common injury seen today in the general and athletic population is the lateral ankle sprain.

Lack of Medical Treatment

From personal experience and observation, most people agree that people view most ankle sprains as a walk-off injury. McKay's 2001 study of basketball players calculated that 56.8% did not seek medical attention for LAS treatment (McKay et al., 2001). Of those injured, 73% of them were previously injured, and 25.9% of the 73% who were injured before did not seek out medical treatment for their previous injury (McKay et al., 2001). This mentality set by the sports community of walking it off and the injury has been discounted given the accumulating evidence of recurrent injury and chronic conditions.

A recent study observed how many people seek out medical treatment for lateral ankle sprains. Results revealed that 64% of the participants did not seek medical treatment after their initial LAS (Hubbard-Turner, 2019). The participants filled out questionnaires and both FAAMS (Foot and Ankle Ability Measures). Results showed that the people who did not seek any medical attention had worse function and perception of function. Along with that, those who did not seek out medical attention saw more ankle sprains since the initial injury (4.7 vs. 1.9) and more incidents of giving away each month (3.8 vs. 1.1) (Hubbard-Turner, 2019). This data confirmed that people who do not seek medical treatment are far worse off than those who did, even though all participants were in the CAI category (Hubbard-Turner, 2019). The authors present the idea that the people who did seek treatment, their initial treatment was not enough; for example, people who did seek medical treatment but went to the ER were sent home with the P.R.I.C.E (protection, rest, ice, compression, elevation) principle, which yes does help reduce symptoms but that does not alone in itself fix all the problems that come after the initial injury. This study also shows that even though everyone had CAI, their level of functionality was very different.

These studies confirm there is a lack of medical treatment for lateral ankle sprains, a walk-it-off culture around the injury, and this needs to be fixed. “LAS needs to be recognized as a substantial orthopedic concern that must be treated and managed as such” (Hubbard-Turner, 2019). We know lateral ankle sprains have a high prevalence, high recurrence, are high risk in certain groups, and, if left untreated or mistreated, will lead to debilitating effects and a dysfunctional lifestyle with the development of CAI and posttraumatic osteoarthritis and possibly osteoarthrosis in a connecting joint. If Ebbets’ foot drills can prove to have use for rehabilitation for strengthening muscles, sensorimotor pathways, and proprioception, then maybe they could be used universally in rehabilitation to combat the injury from becoming debilitating and be used in healthy and high-risk groups to prevent injury.

Long Term Effects of Chronic Ankle Instability

Chronic ankle instability (CAI) as defined by Hertel & Corbett,2019:

> “Chronic ankle instability is a condition characterized by recurrent sprains or perceptions of the ankle giving way; ongoing symptoms such as pain, weakness, or deducted ankle range of motion; diminished self-reported function, that last more than a year from the initial injury” (Hertel & Corbett, 2019).

Eight primary components make up the newest chronic ankle instability model: primary tissue injury, pathomechaincal impairments, sensory-perceptual impairments, motor behavioral impairments, personal factors, environmental factors, interactions of components, and the clinical outcomes (Hertel & Corbett, 2019). Each of the components uniquely affects the person's experience of CAI.

Primary tissue injury occurs from the initial lateral ankle sprain (LAS) and is followed by the second component, pathomechaincal impairments (Hertel & Corbett, 2019). Pathomechaincal impairments are structural abnormalities such as restrictions in soft tissues and range of motion, and if left untreated, they can lead to further injury and or recurrent sprains (Hertel, 2002; Hertel & Corbett, 2019).

Sensory perceptual impairments include diminished somatosensation, pain, perceived instability, kinesiophobia, self-reported function, and health-related quality of life (Hertel & Corbett, 2019). Motor behavioral impairments included deficiencies and alterations in reflexes, neuromuscular inhibition, muscle weakness, and balance deficits (Hertel & Corbett, 2019). Studies demonstrate alterations in muscle activity and timing of proximal and distal muscles of the ankle, which can all add to muscle dysfunction (Delahunt et al., 2006; Feger et al., 2015; Kim et al., 2019).

Neuromuscular inhibition has been well studied in patients with CAI, mainly by the H reflex is (a stretch reflex that represents spinal level motor control), showing that people with CAI had inhibition of the H-reflex not only on the side of injury but bilaterally and did not only the distal muscles but the proximal muscles as well (Bowker et al., 2016; Hertel, 2008). These alterations in H-reflex would support the idea of central forward feed alterations, with its effects bilaterally and globally around the body that other studies have reported (Pietrosimone & Gribble, 2012; Webster et al., 2016).

Muscle weakness has been thoroughly studied, and the studies reviewed showed weakness in subjects with CAI in inversion, eversion, and plantar flexion in either concentric or eccentric actions (Hertel & Corbett, 2019). Balance is also an impairment that can stem from muscle weakness and neural inhibition. Ankle instability and balance deficiencies were some of the first connections made in the literature (Freeman, 1965; Freeman et al., 1965). Balance impairments have been seen in both static and dynamic stability (Hertel & Corbett, 2019). Confirmed by the unipedal stance test and the star excursion balance test, both showing that CAI subjects performed poorly compared to their healthy counterparts (Eechaute et al., 2007; Gribble et al., 2012). Altered movement patterns have been shown with CAI subjects, from walking, running, jumping, and landing compared to controls, their bodies have adapted by changing when and how muscles activate and how the body is positioned to perform the tasks (Delahunt et al., 2006; Doherty et al., 2015; Son et al., 2019). These motor impairments could be seen as a flow chart, one leading or contributing to the other. The last thing that this leads too and if not one of the most important is reduced physical activity. It has been seen that patients with CAI choose to participate less in physical activity because of their instability (Hubbard-Turner & Turner, 2015).

These components all come together to form chronic ankle instability (CAI). CAI is a multifactored complex condition that leads to chronic impairments that negatively affect the body globally if developed and not treated. Initial injury and how people respond creates their circumstances. After the initial injury, how impairments and perceptions are addressed through rehabilitation are significant factors to patient return from the initial injury and CAI's possible development (Caldemeyer et al., 2020; Hertel & Corbett, 2019). For example, during rehabilitation, the focus may be on pathomechaincal impairments. However, the patient still perceives instability or is not comfortable in a certain position, which can, in turn, lead to further and recurrent injury because of the perception the patient has of the injury, and this can alter how the patient makes their body respond.

With the development of CAI, another long-term problem has arisen called Posttraumatic Osteoarthritis (PTOA). PTOA is a form of osteoarthritis (OA) caused by damage from ankle sprains, osteochondral lesions, and ankle fractures affecting the cartilage, articular surface, and joints (Song et al., 2019; Valderrabano et al., 2006). Studies report that LAS contributed up to 22% of all osteoarthritis cases involving the ankle, and 80% of that original 22% were PTOA cases (Saltzman et al., 2005; Saltzman et al., 2006; Valderrabano et al., 2009). Of the PTOA from ankle sprains, 50% developed from people with a single LAS, and the other 50% were from recurrent sprains or CAI (Saltzman et al., 2005; Saltzman et al., 2006; Valderrabano et al., 2009). There is a clear link between LAS and PTOA, but more research is needed to understand their relationship entirely.

In the 2016 Ankle Consortium, the development of the PTOA was discussed and its contributions to ligamentous injury and instability (Gribble et al., 2016). After the initial injury, follow-ups from 11to 20 years found a range from 13% to 48% of participants having radiographic evidence of OA at 51 to58 years old. One study highlighted that 8.7% of PTOA cases had evidence from an acute LAS, but the duration of time was not included (Canale & Belding, 1980; Lofvenberg et al., 1994). Another study that followed up using arthroscopic evaluation revealed that 55% of participants evaluated with CAI had cartilage lesions, with evaluation at less than two years from initial injury (Hintermann et al., 2002). They noted that since most people in the studies had complaints of pain, that percentage could be higher for those who have the same injuries but do not seek medical attention (Gribble et al., 2016). These studies help build the bridge of evidence between LAS and the development of OA and PTOA.

Another highlight of the consortium research was CAI and LAS copers and their T2 relaxation times, which shows collagen integrity and importantly noted, the age range was from 24.5 to 25.3, with their initial injuries being within the last five years (Golditz et al., 2014). These findings are significant because the study shows that even in this asymptomatic population, the joint's degeneration can be seen at a shorter time frame than those who are 50 years old with end-stage OA. Still, more research is needed to know the relationship between early degeneration and end-stage OA (Gribble et al., 2016). These studies help reveal that a single LAS may be enough to start degenerative changes and could lead to OA development faster than previously believed. Asymptomatic people may further accelerate their path to OA due to being asymptomatic.

In 2019, Song et al. investigated the association of ankle injury and OA in retired NFL football players with a history of ankle sprain and surgery. Results revealed that 37.6 % experienced OA in any joint in their lifetime. 58.1% reported of history of ankle injury (Song et al., 2019). An increase of ankle sprains showed a trend of increased reporting OA, and around 37% of players with an ankle injury but who did not need surgery reported OA. The ankle surgery group had the highest prevalence of 1.66 (1 to2 sprain), 1.22 (3 to 5 sprains), and 2.10 (6 or more) (Song et al., 2019). The results helped confirm with an increase in ankle sprains, there was an increase in reported OA, and a history of ankle injury is associated with an increased risk of developing OA. Even though they did not report what joint the OA was located in, these results can help support newer studies looking for linkage of an ankle injury to other lower extremity OA like the knee (Song et al., 2019). To differentiate between PTOA and OA, PTOA would be at the joint where the injury had occurred and OA where the injury affected another joint. This study helps confirm that ankle injury and its degenerative outcomes affect even in the elite athletes and that there may be a linkage between ankle injury and PTOA and possible development of OA somewhere else in the lower extremity as well.

CAI and PTOA are degenerative and disabling conditions that affect all populations and may start to develop after the initial injury. CAI and PTOA could be seen as two fuses being lit at the same time. After the initial injury, how the patient responds, perceives, and rehabilitates the injury will dictate their outcome. If the patient falls into the CAI category, it can be assumed that they may develop OA. These conditions are limiting, restrictive, and affect people's quality of life.

Quality of life is patient-based goals and is important to the health care provider and the patient to optimize patient outcomes. Quality of life can be assessed with HRQOL questionnaires (health-related quality of life), which is a multidimensional social, physical, psychological approach to health care (Houston et al., 2014). A 2014 study used seven questionnaires to assess HRQOL (Houston et al., 2014). The authors concluded, based on the results that quality of life is lower in people with CAI because of decreased function, perception of decreased function, and increased fear of injury (Houston et al., 2014). This study helps to confirm that people who fall into CAI have a lower quality of life.

The following year, the same author published a systematic review that investigated HRQOL outcome measures via questionnaires in people with CAI, copers who can perform functional activities despite injury and healthy. The investigators created three categories, CAI and copers, CAI and healthy, and copers and healthy (Houston et al., 2015). In the CAI and healthy control group, CAI participants reported lower overall HRQOL outcomes than healthy controls (Houston et al., 2015). Compared to the healthy group CAI, results showed higher disability, region-specific dysfunction, and a heightened fear of injury. CAI revealed that compared to coper, CAI had a lower score HRQOL. The CAI had more functional deficits and increased fear of injury than the Copers (Houston et al., 2015). Nevertheless, it should be noted that there was some measurement error in the calculation of fear (Houston et al., 2015). Copers vs. healthy group had mixed results, with seven of the nine comparisons between the questionnaires showed that copers have a lower HRQOL (Houston et al., 2015). Overall, the coper group reported a decreased function compared to the control and increased fear (Houston et al., 2015). This systematic review showed that the overall CAI group compared to healthy control and copers have a lower perception of function, actual function, and a heightened fear of injury. While the study did show mixed results with coper vs. healthy, it was clear that copers have deficiencies compared to healthy but are much better than the CAI group overall (Houston et al., 2015). This could mean that copers could perceive to be fine and continue to participate or be active on an unstable and slightly impaired ankle, which could lead them to CAI and further injury later. This study confirms that people with CAI have a lower quality of life compared to their counterparts.

The Problem & Conclusion

Lateral ankle sprains in the general and athletic population are the most prevalent of all ankle injuries (Herzog et al., 2019). Considering these injuries are so prevalent, those affected tend not to seek medical treatment, and refusal to seek treatment may contribute to the higher reinjury rates seen in those who sustain LAS injuries and far worse outcomes (Hubbard-Turner, 2019). Deficits and alterations of ankle function have been documented from acute lateral ankle sprains to later during CAI and PTOA, and it is these alterations that healthcare professionals focus on during rehabilitation. The muscles play a critical role in the lower extremity's functional motion; muscular strength, excitability, and dynamic postural control all play critical roles in controlling the foot's positioning, timing of positioning, and movement during our most basic movement walking. If not properly addressed, the previously injured area can see residual symptoms one to seven years after the initial sprain (Anandacoomarasamy & Barnsley, 2005; Delahunt et al., 2010; Konradsen et al., 2002). Multiple injuries to the ankle can lead to two degenerative conditions, chronic ankle instability and osteoarthritis (specifically posttraumatic osteoarthritis). While these degenerative conditions may start developing simultaneously, usually CAI is the first condition diagnosed, while OA is diagnosed later. Both conditions have shown lower function, sustained alterations, deficits, and lowered health-related quality of life compared to healthy individuals. Dr. Ebbets has created a set of 6 foot drills, claiming that these drills can help to lower the chances of ankle sprains and lessen their severity and prevent or reduce the likelihood of attaining other lower extremity ailments (Ebbets, 2011a). To our knowledge, no research has been done or published on Dr. Ebbets' foot drills. Identifying the activity of the ankle muscles during Ebbets' foot drills is the goal of this study. Completing this goal by using surface electromyography can help fill the gaps between the known muscular deficits and dysfunction seen with LAS.

CHAPTER 3

METHODS

Purpose

The purpose of this study was to identify the sEMG activity of the tibialis anterior, fibularis longus, soleus, and posterior tibialis during Ebbets' foot drills compared to the muscle sEMG activity during a normal gait.

Null Hypothesis

H_o: Activity (mean RMS) of the muscles of the lower leg (tibialis anterior, fibularis longus, soleus, and posterior tibialis) will not differ amongst Ebbets' foot drills when compared to normal gait.

Alternative Hypothesis

H_1: The tibialis anterior will have a greater mean RMS during Ebbets' foot drills, walking forwards on the heels, on the insides of the feet, toes pointed in, and toes pointed out compared to normal gait.

H_2: The tibialis posterior will have a greater mean RMS during Ebbets' foot drills, walking on the outside of the feet, walking with toes pointed in, walking with toes pointed out, walking on the insides of the feet, and walking backwards on the toes compared to normal walking.

H_3: The fibularis (peroneus) longus will have a greater mean RMS during Ebbets' foot drills, walking forwards on your heels, walking toes pointed out, walking on the insides of your feet, and walking backwards on your toes compared to normal walking.

Participants

Twenty-two participants enrolled by a convenience sample, with one participant being excluded due to having pains 2 > 10 in the ankle during strength testing. All participants were in good physical health. Participants had strong, stable, restriction and impairment-free lower legs and gait patterns. All aspects of the investigation were explained to the participants, and then they provided written informed consent prior to data collection. Data collection procedures took approximately 90 minutes to complete.

Inclusion criteria.

1. Lower extremity pain during gait < 2/10 (Numerical Pain Scale)

2. Unrestricted foot and ankle motion (Measured with a goniometer)

3. At least 18 and < 30 years of age

Exclusion criteria (any 1 excludes).

1. Lumbar back pain ≥2/10 (Numerical Pain Scale)

2. History of the lower leg, ankle, or foot fracture reported in history.

3. The participant reports during history an episode of ankle instability or “giving out” (<2 in the past 6 months) (See appendix III)

4. Systemic musculoskeletal disease reported in history

5. Ankle or foot surgery reported in history.

6. Lower extremity pain ≥2/10 (Numerical Pain Scale)

6. Evidence of acute ankle injury by evaluation, history, and observation.

7. Evidence of chronic ankle instability from questionnaires (FAAM ADL < 90%, FAAM Sport < 80%, IdFAI > 10)

IRB Approval

This study was approved (IRBNET # 1545872-1) by the Marshall University Institutional Review Board (IRB) (See Appendix I). All participants provided written informed consent before participation (See Appendix II).

Instrumentation

The sEMG was recorded using a four-channel BioNomadix (BIOPAC Systems Inc., Goleta, CA), with BioPac M150 data collection and Acknowledge data processing software.

Measurements for MVIC were collected using a handheld dynamometer (micfoFET2, Hoggan Scientific LLC, Salt Lake City, UT). Validity and Reliability for collecting lower limb muscle strength have been established (Mentiplay et al., 2015).

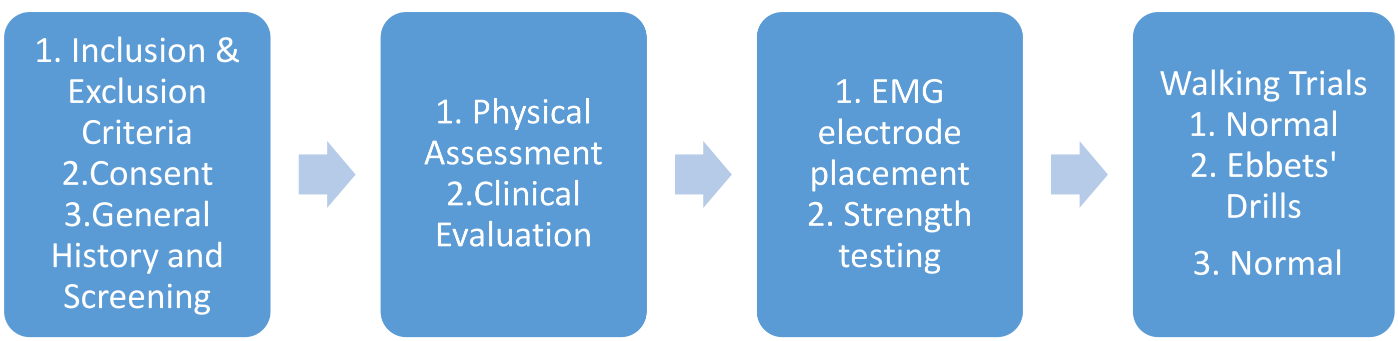
Experimental Design

A repeated measure design was used to test the proposed hypothesis, and between trials, comparisons were made.

Protocol

Participants came on the day agreed upon wearing activewear with access to both feet. Upon arrival, participants were informed of the proposed project, what they would complete, and why the research was being done. Following this introduction and informed consent, participants completed demographic information and health history. When all the information and observation of the patient was collected, then the Identification of Functional Ankle Instability (IdFAI) questionnaire and Foot and Ankle Ability Measure (FAAM) questionnaires were filled out by the participant (Appendix IV and V). Following the questionnaires, the participant's ankle range of motion was measured on both feet. Next, clinical ankle assessment for pain was conducted using the anterior drawer, talar tilt, and external rotation test on the -non-dominant leg. Next, the participant completed the star excursion balance test and the unipedal stance test with the nondominant leg as the fixed/test leg (Figure 1B). Following, participants non-dominant leg was cleaned vigorously with alcohol wipes and the hair trimmed if necessary following SENIAM skin preparation, after which the nondominant leg had surface electromyography (sEMG) electrodes applied at the SENIAM (Hermens et al., 2000) locations for the tibialis anterior, peroneus longus, and soleus. For the posterior tibialis, a modified intramuscular location (Chapman et al., 2006) was reported with diagnostic ultrasound and pilot testing. After the electrodes were placed, participants completed strength measure trials of dorsiflexion, plantarflexion, inversion, and eversion (Figure 1C) by completing maximal voluntary isometric contraction (MVIC), which was also used for sEMG normalization. Participants then performed a normal walking trial over a 25-yard straight-line course marked off by tape at self-pace and one minute rest. Participants then were instructed on how to perform Ebbets' foot drills before each trial and practiced each drill until comfortable. Next, participants performed each Ebbets' foot drills in one trial in the order the drills were shown in Dr. Ebbets' papers, forwards on heels, outside of feet, inside of feet, toes pointed in, toes point out, and backward on toes, and participant will rest one minute after each trial. Finally, participants performed an additional trial of normal walking (Figure 1D).

Figure 1. Flow Chart of Procedures. A visual representation of how the study will proceed.



Procedures

Demographics.

Before any experiment protocol, the participant's demographic information was recorded. Their height (Avg 168.18 cm ± 11.00 cm), weight (84.74 kg ± 27.56 kg), BMI (26.3 kg/m² ± 5.5

kg/m²), age (23.67 years ± 2.29 years), sex (10 males, 11 females), side dominance of feet (18 right, 3 left). The identification of functional ankle instability (IDFAI) and the foot and ankle ability measure (FAAM) were also collected prior to the experiment protocol. Then ankle range of motion (ROM) and ankle strength were collected. For this study, the non-dominant side was used for strength and sEMG measures.

	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m²)	IDFAI	FAAM ADL (%)	FAAM Sport (%)
Mean	23.67	84.74	168.18	26.3	9.45	99.3 %	98.8%
Standard Deviation	2.29	27.56	11.00	5.5	8.84	3.3 %	3.5%

Table 1. Demographics
Table 1 shows the mean and standard deviation for the participants' age, weight, height, BMI, scores of the IDFAI, FAAM ADL percentage, and FAAM Sport percentage.

Range of Motion and Strength and Balance	
	Mean ± Standard Deviation
Range of motion (degrees)	
Left Dorsiflexion	27.4° ± 5.2°
Left Plantarflexion	28.2° ± 7.6°
Left Inversion	32.2° ± 8.8°
Left Eversion	29.7° ± 8.7°
Left Toe Flexion	38.3° ± 9.6°
Left Toe Extension	40.4° ± 6.4°
Right Dorsiflexion	28.7° ± 5.3°
Right Plantarflexion	28.8° ± 7.3°
Right Inversion	32.0° ±7.1°
Right Eversion	31.2° ± 11.8°
Right Toe Flexion	38.3° ± 6.7°
Right Toe extension	37.9° ± 6.5°
Strength (lbs.)	
Dorsiflexion	49.9lbs ± 9.2lbs
Plantarflexion	49.4lbs ± 12.6lbs
Inversion	32.5lbs ± 7.5lbs
Eversion	33.4lbs ± 7.1lbs
Star Excursion Balance Test (% of leg length)	
Anterior	89.8% ± 21.1%
Posterior medial	83.5% ± 21.4%
Posterior lateral	78.1% ± 20.8%

Unipedal Balance Test (seconds)	
	43.6 secs ± 6.4 secs

Table 2. Range of Motion and Strength Measurements
Table 2 shows the mean and standard deviation of the range of motion for dorsiflexion, plantarflexion, inversion, eversion, toe flexion, and toe extension of the participant's left and right feet. It also shows the mean and standard deviation for the MVIC strength measurements taken for dorsiflexion, plantarflexion, inversion, and eversion. Finally, it gives the mean and standard deviation of the Star excursion balance test and the single-leg balance test. The threshold for CAI for the star excursion balance test (SEBT) for the three directions, anterior <80%, posterior medial <90%, and posterior-lateral <82% of the participant's leg length (Hertel et al., 2006). The unipedal balance test CAI threshold was < 43 seconds (Springer et al., 2007).

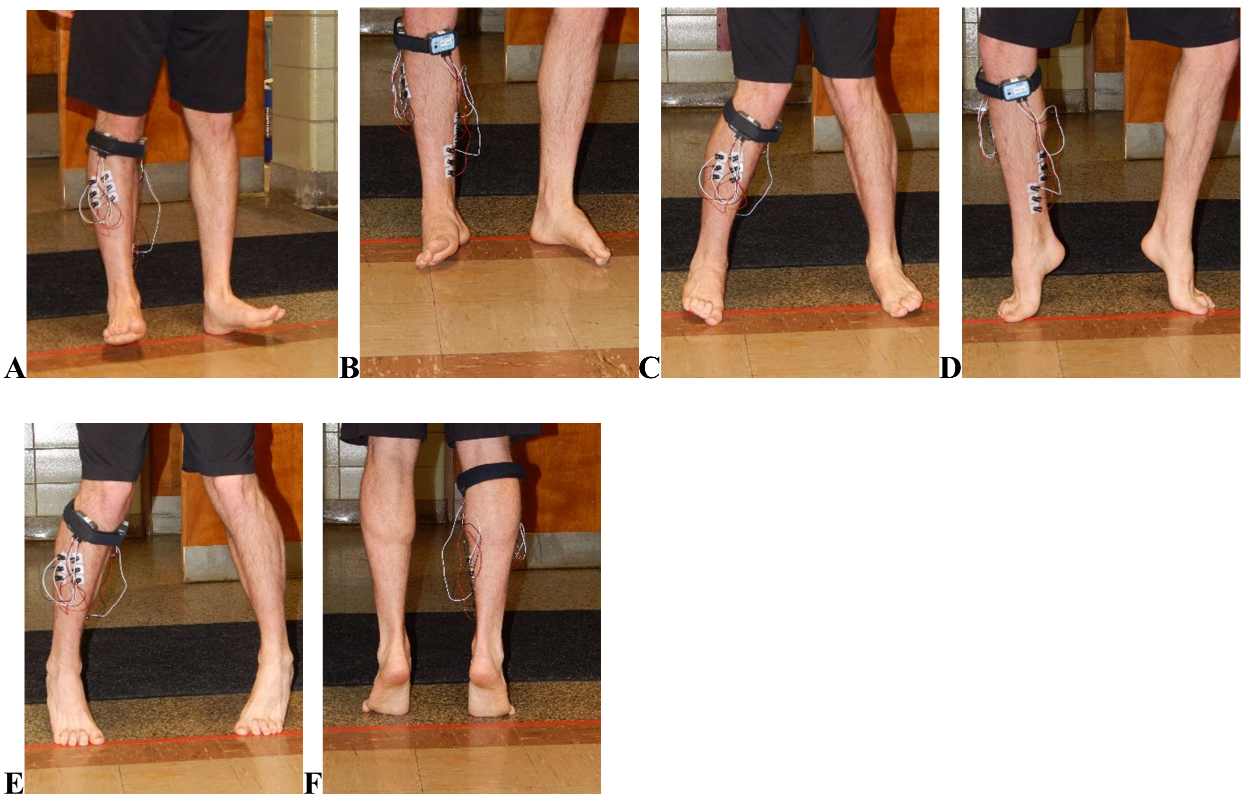
<u>Ebbets' Foot Drills.</u>

The Ebbets' foot drills consist of six exercises performed while walking (Ebbets, 2011a). Each walking trial is performed with the participant holding their feet in different positions while walking a 25-meter straight-line course.

The participant walks forward, holding their toes off the ground, walking on their heels (Figure 2A). The participant walks forward on the outside of their feet, walking in an inversion position (Figure 2B). The participant walks forward on the inside of the feet, walking in an eversion position (Figure 2C). The participant walks forward, holding their feet in a toe-out position (Figure 2D). The participant walks forward with their feet in a toe in position (Figure 2E). The participant walks backward, holding their heels off the ground, walking on their toes (Figure 2F). In Dr. Ebbets' foot drills procedures, walking forwards on the heels is done in shoes to prevent bruising when done daily, but to keep consistency in the collection, this drill during our protocol was done without shoes (Ebbets, 2011a).

Participants were instructed on how to perform each exercise and practice the exercise before the trial. Once the participant feels comfortable and proficient in performing the exercise, they were asked to stand quietly for a five second period at the start of data collection to minimize noise for the EMG collection. The participant will start the trial after the quiet period, and once they reach the 25-yard marker at the end of the walkway, the participant will stop and pause without turning around. Once that trial has been completed, they will return to the starting area and rest for at least one minute before preparing for the next trial.

Figure 2. Foot Positions of the 6 Exercises of Ebbets' Foot Drills.



Note: The photos above demonstrate the six positions of Ebbets' foot drills. A) Walking forwards on the heels. B) Walking on the outsides of the feet (inversion). C) Walking on the insides of the feet (eversion). D) Walking on the tiptoes with toes pointed out. E) Walking on the tiptoes with the toes pointed in. F) Walking on the tiptoes backward.

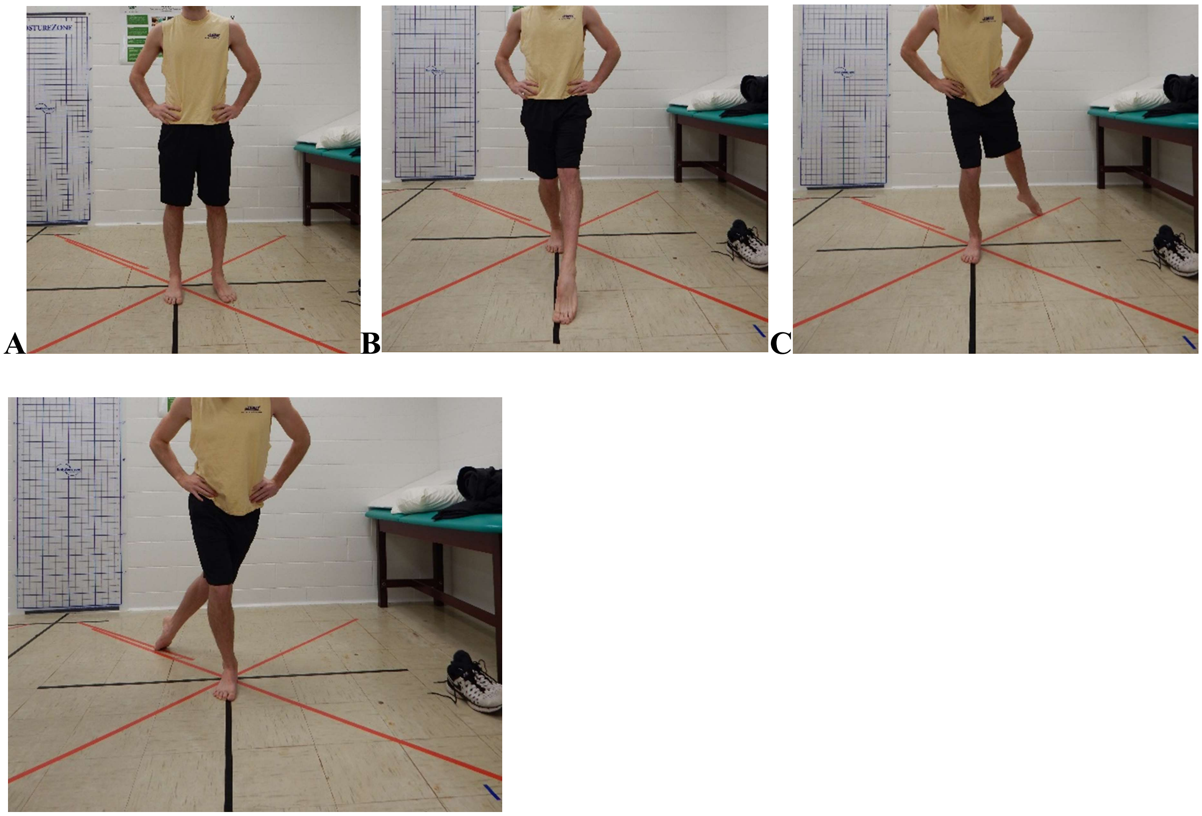
Ankle Function Surveys.

Participants will complete the Identification of Functional Ankle Instability questionnaire (IdFAI) (Appendix V) and Foot and Ankle Ability Measure (FAAM) (Appendix IV) questionnaires. The IdFAI is a 10-item questionnaire designed to assess participants with functional ankle instability (Simon et al., 2012). The IdFAI scores range 0 – 36 (0 = no disability, 36 = great disability) (Simon et al., 2012). The reliability (intraclass coefficient (ICC) range 0.922 – 0.978) and responsiveness (Minimal detectable change (MDC)= 3.6) of the IdFAI have been established (Gurav et al., 2014; Mineta et al., 2019). A score great than 11 has been associated with functional ankle instability (Simon et al., 2012). The FAAM is a 29 item (21 items assess the activity of daily living ((ADL)), and eight items assess sports activity) scale designed to assess the function of the participant's foot and ankle (Martin et al., 2005). The ADL 21 item scale ranges 0 – 84, (0 = great difficulty, 84 = no difficulty) and the eight-item sport activity scale ranges 0 - 32 (0 = great difficulty, 32 = no difficulty) (Martin et al., 2009). The general scoring for the FAAM is converted into a percentage, the higher percentage, the greater function. Following the interest of this study, we used (Carcia et al., 2008) scoring system: A score of < 90% on the activities of daily living (ADL)scale or a score of < 80% on the sport scale indicates a participant with chronic ankle instability (Carcia et al., 2008). The reliability of the FAAM ADL scale was (ICC = 0.89) and responsiveness (MCD = 5.7), and for the FAAM sports scale was (ICC = 0.87) and responsiveness (MCD = 12.3) has been established (Martin et al., 2005).

Star Excursion Balance Test.

The star excursion balance test (SEBT) initially developed in 1995 (Gray, 1995) was performed in the SEBT area we created (Figure 3), as described by Robinson (Robinson & Gribble, 2008) SEBT is used to assess dynamic stability during the assessment section of the protocol. The participant stands on the test leg looking forward, with their hands resting on their hips (Robinson & Gribble, 2008). The investigator instructs the participant to reach with the non-weight-bearing leg as far as possible, lightly touching the ground with the most distal part of their foot and returning to a bilateral stance (Robinson & Gribble, 2008). The investigator places a mark on the floor at the point that the participant touches the ground to complete a trial. (Robinson & Gribble, 2008). If the participant touches the ground heavily, loses their balance, or cannot return to a bilateral stance, the trial is not included in the analysis (Robinson & Gribble, 2008). The SEBT was scored as the distance between the posterior aspect of the foot (which was placed on the center of the crossing of the tapes) of the stance leg and the point on the ground that the test leg touches (measured in centimeters). The SEBT tests performed were the anterior, posterior-medial, and posterior-lateral direction. (Gribble et al., 2012; Robinson & Gribble, 2008). Interrater reliability of the SEBT has been well established, with an ICC range of 0.67 – 0.87 is reported (Kinzey & Armstrong, 1998). The threshold for CAI for the star excursion balance test (SEBT) for the three directions, anterior <80%, posterior medial <90%, and posterior-lateral <82% of the participant's leg length (Hertel et al., 2006). Participants were instructed on how to perform the SEBT and conducted several successful practice trials before data collection. Successful trials were counted if they do not touch the ground with the foot heavily, lose balance, and return to starting position. Participants will complete three successful trials in each direction; the mean of the three trials was used for data analysis.

Figure 3. Progression of the Star Excursion Balance Test.

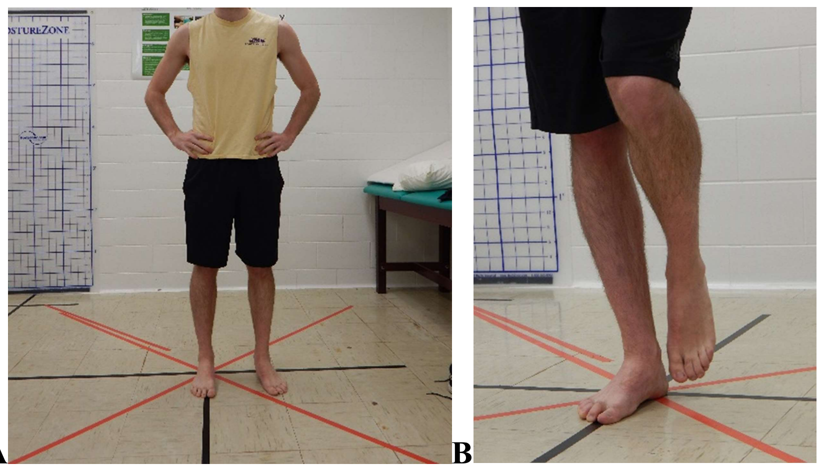


Note: These figures show how the SEBT progresses from the start position to the reaching out positions. A) starting stance of the SEBT, B) Anterior, C) Posterior Lateral, D) Posterior Medial

<u>Unipedal Stance Test.</u>

The unipedal stance test (UPST) was used to assess static stability during the assessment section of the protocol. The participant is standing barefoot on both legs, their hands placed on their hips, and their eyes open looking forward. Then the investigator instructed the participant to focus on a star marked on the wall, hands on the hips, to march in place until told to start balancing, then the participant will place all their weight on the test leg and raise the other leg off the ground while crossing arms over chest. The participant raises the non-weight-bearing leg so that the balance leg's big toe is level with but not touching the medial malleolus of the ankle of the stance leg. Time starts as soon as the participant goes into single leg balance, and the test ends when; 1) the participant uses their arms to maintain their balance, 2) uses their raised foot to maintain their balance, 3) moves the weight-bearing foot, or 4) time elapses past 45 seconds (Springer et al., 2007). The test is scored as the elapsed time between the point when the participant raises their foot to when they need to attempt to regain their balance, measured in seconds. If the participant cannot raise their foot from the ground, the test is zero seconds. The intratester reliability of the UPST has been reported to be excellent (ICC range 0.989 -0.996) (Springer et al., 2007). The threshold in scoring the UPST for having CAI or not was a score < 43 seconds (Springer et al., 2007).

Figure 4. Unipedal Balance Test.



A B

Note: The progression of the UPST, the participant, will march in place until given instruction. 4a) shows the start position before marching and the instruction of what foot will be lifted. 4b) shows how the foot is aligned with the body and held during the test.

Clinical Evaluation

Anterior Drawer Test for the Ankle.

The anterior drawer test for the ankle tests the anterior talofibular ligament integrity (Prentice, 2017). The participant was seated with their knee flexed and ankle dorsiflexed to 10°. The examiner grasps the participant's heel with one hand and the participant’s tibia with their other hand. The examiner then applied an anteriorly directed force on the participant’s heel

(Prentice, 2017). A positive test is recorded when the examiner can sense the talus side from under the participant's tibia without a solid end feel to the movement of the talus.

Talar Tilt Test.

The talar tilt test tests the anterior talofibular and calcaneofibular ligaments (Prentice, 2017). The test is performed with the participant seated with their knee flex and their ankle in 10° plantar flexion. The examiner grasps the participant's tibia with one hand and grabs the participant's heel with their other hand. The examiner then applied a medially directed force to force the ankle into inversion (Prentice, 2017). A positive test is recorded if there is greater than 20° inversion or if the examiner does not feel a firm end to the inversion motion.

External Rotation Test.

The external rotation test checks the integrity of the ankle syndesmotic ligaments. The test is performed with the participant sitting and their knee flexed (Prentice, 2017). The examiner grasps the participant's lower leg with one hand and their heel while using their forearm to hold the participant's ankle in a neutral position in the sagittal plane. The examiner then applies a force that produces an external rotation of the ankle (Prentice, 2017). A positive test is recorded if the participant experiences pain over the syndesmotic ligament or if the examiner can sense an external rotation of the talus in the ankle mortise.

Strength

The ankle complex's MVIC (maximal voluntary isometric contraction) strength was assessed using a handheld dynamometer (microFET2, Hoggan Scientific LLC, Salt Lake City, UT) and used to normalize the EMG data. Strength was evaluated as the four primary ankle motions, dorsiflexion, plantar flexion, inversion, and eversion. Strength was measured in kilograms (Kg); three trials of each movement were performed with a 30-second rest between trials. The mean of the three trials was used for analysis. Participants were asked to rate their pain on a numerical pain scale (0 = no pain, 10 = most extreme pain) after each maximal strength trial.

Dorsiflexion (Anterior Tibialis).

The tibialis anterior strength was assessed with the participant lying prone with their legs hanging off the table (Figure 5) (Magee, 2014). The examiner stands by the participants' feet, and the dynamometer is placed over the medial dorsal side of the foot following the 1st metatarsal. The participant was instructed to dorsiflex and invert the foot. The examiner resists the motions.

Figure 5. Position for Dorsiflexion Strength Testing.

Note: The participant is lying prone with knees hanging off the table. The examiner is behind them with the dynamometer placed dorsal medial line following the 1st metatarsal.

Eversion (Peroneus Longus).

The strength of the fibularis longus was assessed with the participant sitting with their legs hanging off the table knees flexed (Figure 6) (Magee, 2014). The examiner kneels next to the participant supporting the participant's lower leg. The dynamometer is placed over the foot's lateral border following the base of the 5th metatarsal (Magee, 2014). The participant was instructed to start in plantar flexion and evert the foot. The examiner resisted the motions.

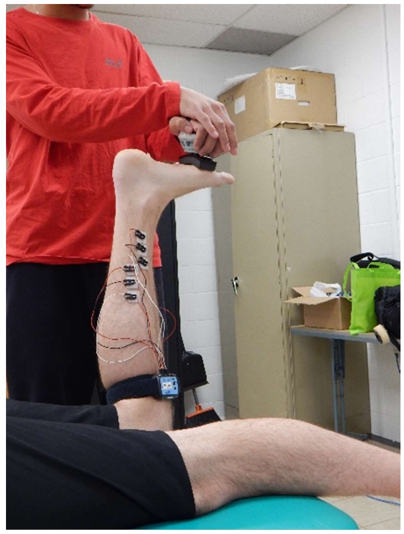
Figure 6. Position for Eversion Strength Testing.

Note: The participant is sitting with legs hanging off the table, knees flexed. The examiner is kneeling, supporting the leg. The dynamometer is placed on the lateral border of the foot on the base of the 5th metatarsal.

Plantar Flexion (Soleus).

The soleus' strength was assessed with the participant lying prone with the knee flexed to 90 degrees (Figure 7) (Magee, 2014). The examiner stands above the participant's feet, supporting their lower leg. The dynamometer is placed over the participant's posterior surface of the metatarsal phalangeal joints. The participant is instructed to plantarflex. The examiner resists the motion.

Figure 7. Position for Plantarflexion Strength Testing.



Note: The participant is lying prone with the target leg flexed at 90 degrees. The examiner is on a stool standing beside. The dynamometer is placed over the ball of the foot following the metatarsal phalangeal joints.

<u>Inversion (Posterior Tibialis).</u>

The posterior tibialis strength was assessed with the participant sitting with their legs hanging off the table, and the examiner kneels at the participant's side supporting their lower leg (Magee, 2014). The dynamometer is placed over the medial plantar surface of the foot near the base of the big toe (Magee, 2014). The participant is instructed to start in plantar flexion, then to invert the foot. The examiner resists the motion.

Figure 8. Position for Inversion Strength Testing.

Note: The participant is sitting with legs off table knees flexed. The examiner is kneeling, supporting the leg. The dynamometer is placed on the medial border of the foot on the base of the great toe.

Electromyography

The surface electromyography (sEMG) was collected from the nondominant leg. From the following muscles, anterior tibialis (AT), posterior tibialis (PT), soleus (SOL), and peroneus longus (PL). The sEMG data collection took place during each MVIC strength trial and each walking trial. The sEMG was recorded using a 4channel BioNomadix (BIOPAC Systems Inc., Goleta, CA), with BioPac M150 Data Collection and Acknowledge Data Processing Software. The sEMG signals were collected at 2000Hz for all the strength measurements, Ebbets' drills, and normal walking.

Electrode placement followed SENIAM recommendations for the AT, SOL, and PL (Hermens et al., 1999). Before electrode measurement and placement, the skin was scrubbed vigorously with alcohol wipes. The AT electrode is placed at a point distal to the fibular head 1/3 the distance between the fibular head and the tip of the medial malleolus (Hermens et al., 1999). The PL electrode is placed distal to the fibular head at a point ¼, the distance fibular head, and the tip of the lateral malleolus (Hermens et al., 1999). The SOL electrode is placed distal to the medial posterior femoral condyle distal to 2/3 the distance between the femoral medial condyle to the medial malleolus (Hermens et al., 1999). The PT electrode is placed distal to the medial femoral condyle ¼ the distance between the posterior femoral condyle and posterior medial malleolus. This position followed a modified location that combined the intramuscular site location (Chapman et al., 2006) and ultrasound to confirm the location where the soleus does not surround the posterior tibialis. Surface EMG signals were collected during all strength measurements, walking trials, and during each of Ebbets' foot drill trials.

Following the collection of all sEMG signals, they were saved for processing. To start in the Acknowledge Software, under the transform tab, a bandpass filter from 20 to 400Hz was applied to the trial, and then a 60Hz notch filter was applied and then saved. Next, the mean root means square (RMS) value for each muscle for normal walking, each Ebbets' foot drill, and strength measurements were analyzed. To complete this analysis, in the Acknowledge Software, under the integrate tab, the root means squared was derived for the whole length of each trial by collecting at the 0.03-time interval and applied to the values and saved. When deriving roots means squared for the strength testing, one sample was collected for each trial, and a mean was calculated through Excel Software. For the walking and Ebbets' foot drills, RMS's mean for each trial was collected and put into Excel Software. For data normalization, strength measurements were used. To complete normalization, in Excel Software, the mean of the root means squares of each muscle trial for Ebbets' foot drills and normal walking were divided by the mean root means square of the MVIC strength measurement for each muscle.

Statistical Analysis

All participant and investigator generated data was recorded on paper documents and then entered into an electronic database for analysis. All statistical analyses were performed with SPSS 22.0 (SPSS, Chicago, Il). Descriptive means and standard deviations were reported for all demographic variables. A one-way repeated measures ANOVA (7 levels, walking, and 6 Ebbet's foot drill trials) were used to evaluate the differences in normalized mean RMS values between trials. Specifically, each muscle's mean RMS value was compared to the normalized mean RMS values of the walking trial. Between trial Post-hoc analysis included paired t-tests to test differences between each Ebbets' foot drill and the walking trial for the anterior tibialis, fibularis longus, and posterior tibialis. Bonferroni correction was used to give an error for multiple comparisons and analyses. Statistical significance was determined at the $P < 0.05$ level.

CHAPTER 4

RESULTS

Tibialis Anterior

The sEMG for the tibialis anterior (TA) displayed statistically greater activity during all Ebbets' foot drill trials than the first walk trial (Figure 9). The drills main effect on the TA was statistically significant ($F_{(114, 6)} = 96.903$, $P < 0.001$, $\eta^2 = 0.836$, $\beta = 1.000$). *Post-hoc* analysis of the TA showed greater muscle activity during all Ebbets' foot drill trials than during the first walk trial. The greatest increases in TA activity were seen during the forwards heel walk drill (mean difference = 0.683, P < 0.001), walking in inversion (mean difference = 0.313, P < 0.001), and the eversion drill (mean difference = 0.237, P < 0.001). Lower increases in TA activity were seen during the toe in drill (mean difference = 0.059, P = 0.013), walking in toe-out (mean difference = 0.040, P = 0.023), and on the toes backwards (mean difference = 0.063, P = 0.025).

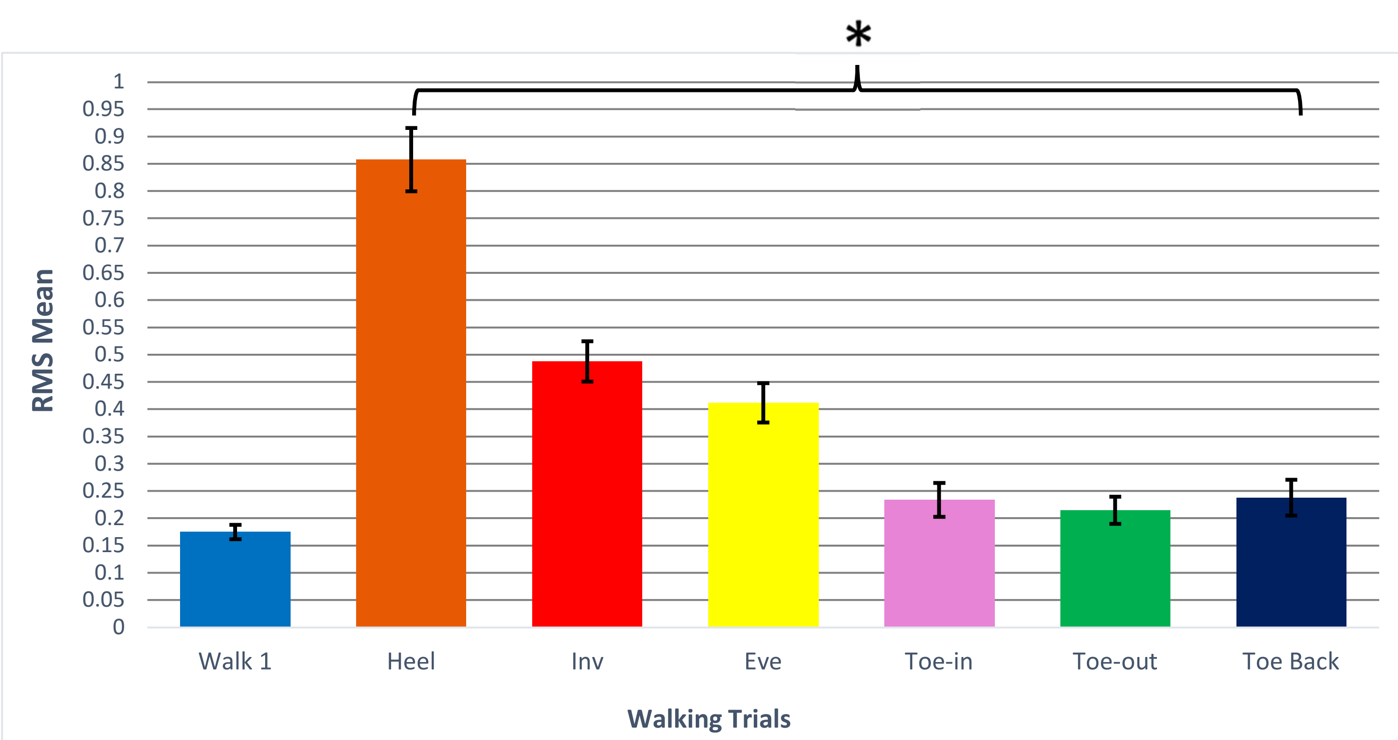


Figure 9 Activity of the Tibialis Anterior During Ebbets' Foot Drills: The figure above depicts the anterior tibialis RMS mean muscle activity of the 6 Ebbets' foot drills compared to Walk 1. The mean RMS is normalized to the mean RMS of the MVIC. The TA sEMG activity was significantly greater during all Ebbets' foot drills than Walk 1. Error bars = standard error of measurement. * =P < 0.05.

Posterior Tibialis

The sEMG of the Posterior tibialis (PT) displayed statistically greater activity during the toe-in, toe-out, and toes backward drills compared to Walk 1 (Figure 10). The drills main effect on the PT was statistically significant ($F_{(114, 6)} = 15.040$, $P < 0.001$, $\eta^2 = 0.442$, $\beta = 1.000$). *Post-hoc* analysis of the PT showed greater activity during the last three Ebbets' foot drills: toe-in, toe-out, and toes backward. The increases in the PT were seen during the toe-in drill (mean difference = 0.504, P < 0.001), the toe-out drill (mean difference = 0.550, P < 0.001), and the toes-backwards drill (mean difference = 0.473, P < 0.001).

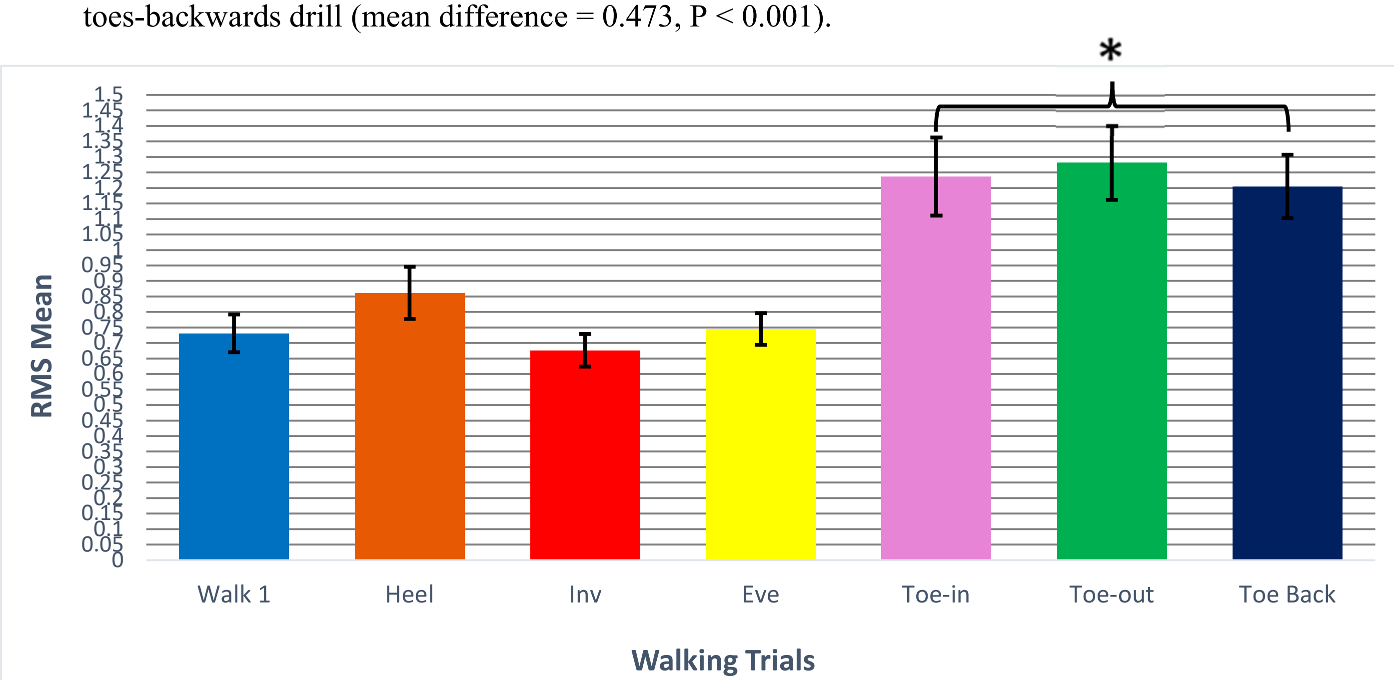


Figure 10 Activity of the Tibialis Posterior During Ebbets' Foot Drills: This figure shows the posterior tibialis' sEMG activity during each of the Ebbets' foot drills compared to walk 1. The mean RMS is normalized to the mean RMS of the MVIC. The drills, walking on toes with toes pointed in, toes pointed out, and toes backward, had significantly greater sEMG activity than walk 1. Error bars = standard error of measurement. * =P < 0.05.

Peroneus Longus

The Peroneus longus (PL) sEMG displayed statistically greater activity during all Ebbets' foot drills except the inversion drill compared to Walk 1 (Figure 11). The drills main effect on the PL was statistically significant ($F_{(114, 6)} = 30.168$, $P < 0.001$, $\eta^2 = 0.614$, $\beta = 1.000$). *Post-hoc* analysis of the PL showed greater activity in all Ebbets' foot drills except drill 3, walking in inversion. The increases in the PL were seen during the forwards heel walk (mean difference = 0.194, P < 0.001), walking in eversion (mean difference = 0.518, P < 0.001), the toe-in drill (mean difference = 0.416, P < 0.001), toe-out walk (mean difference = 0.537, P < 0.001), and on the toes backwards (mean difference = 0.513, P < 0.001).

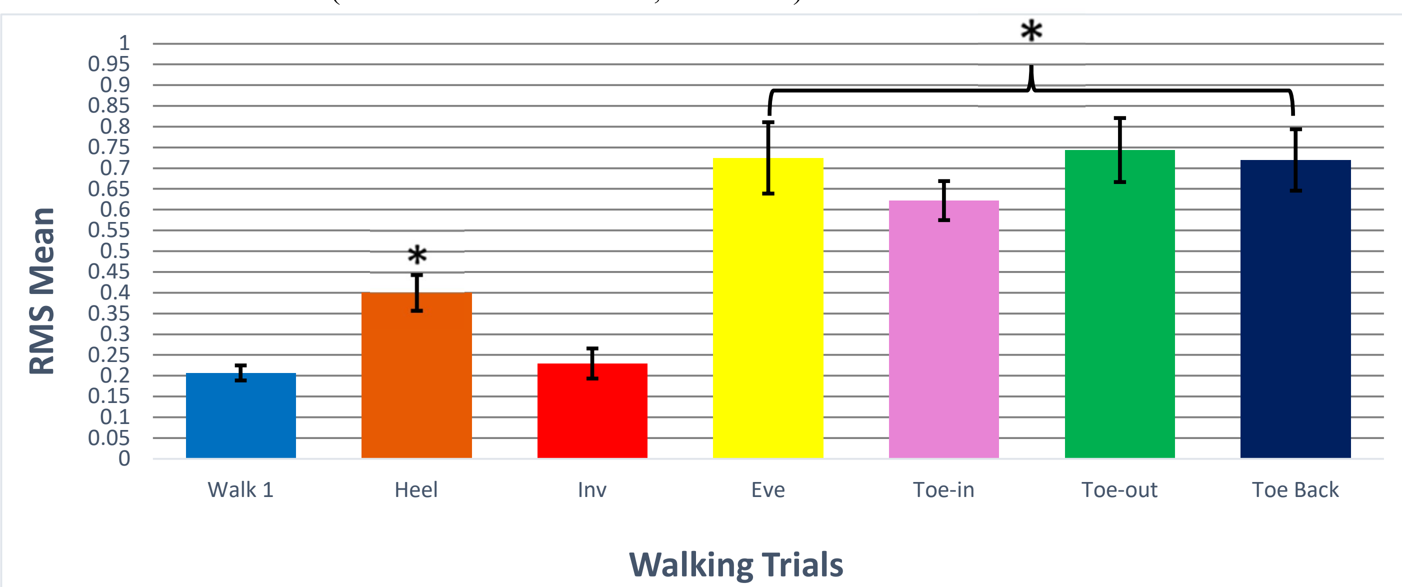


Figure 11 Activity of the Peroneus Longus During the Ebbets' Foot Drills: The figure above shows the sEMG activity of the peroneus longus during each of the Ebbets' foot drills compared to walk 1. The mean RMS is normalized to the mean RMS of the MVIC. All the drills except walking in inversion had significantly greater sEMG activity than walk 1. Error bars = standard error of measurement. * =P < 0.05.

Soleus

The soleus (SL) sEMG showed greater activity during all the Ebbets' foot drills than Walk 1 (Figure 12). The drills main effect on the SL was statistically significant ($F_{(114, 6)} = 6.261$, $P < 0.001$, $\eta^2 = 0.248$, $\beta = 0.998$). *Post hoc* analysis of the SL showed greater activity during all Ebbets' foot drills when compared to Walk 1. The increases seen in the SL were during the forwards heel walk (mean difference = 0.272, P < 0.052), walking in inversion (mean difference = 0.150, P < 0.058), eversion (mean difference = 0.162, P < 0.038), toe-in walking (mean difference = 0.311, P < 0.057), toe-in (mean difference = 0.280, P < 0.045), and backwards on the toes (mean difference = 0.272, P < 0.051).

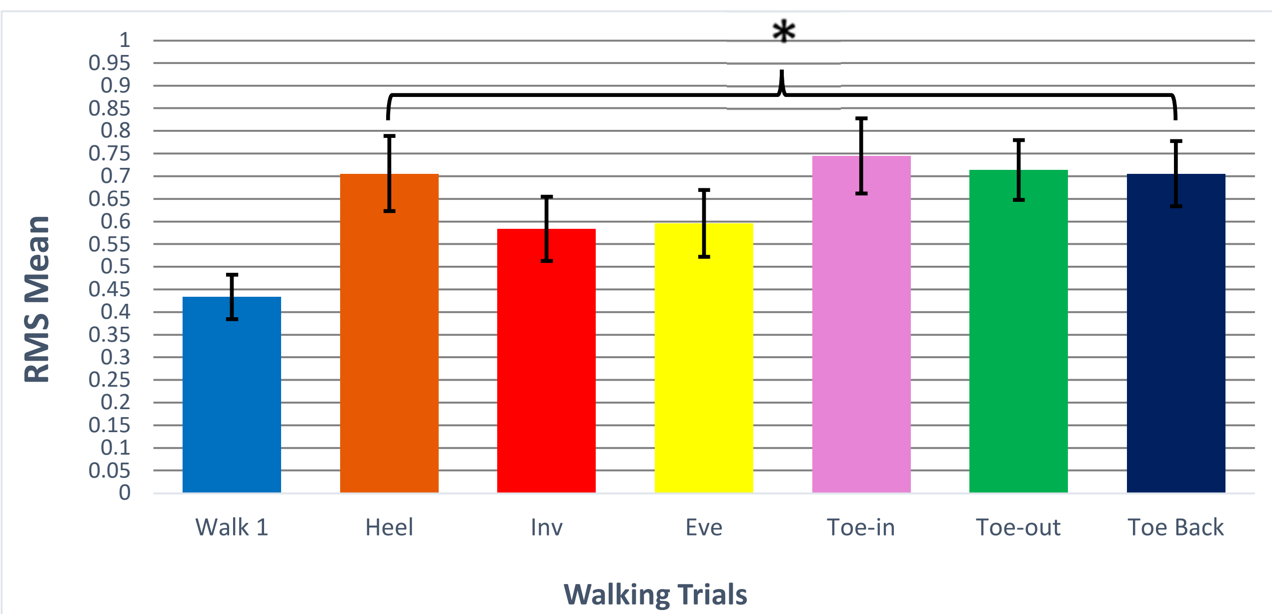


Figure 12 Activity of the Soleus During Ebbets' Foot Drills: The figure above shows the soleus' sEMG activity during each of the Ebbets' foot drills compared to walk 1. The mean RMS is normalized to the mean RMS of the MVIC. All the drills had significantly greater sEMG activity compared to walk 1. Error bars = standard error of measurement. * =P < 0.05.

Walk 1 vs. Walk 2

The sEMG during the two walk trials for the four muscles tested are presented in Figure 13. The sEMG for the TA was greater (mean difference = 0.0121, t = -2.418, DF = 19, P = 0.032) in the second walk trial than the first. The PL showed a trend towards a greater activity (mean difference = 0.0128, t = -2.079, DF = 19, P = 0.051) in the second walk trial compared to the first trial. The sEMG for the PT (mean difference = 0.0028, t = 0.146, DF = 19, P = 0.886) and SL (mean difference = 0.0126, t = 0.925, DF = 19, P = 0.367) did not show a statical difference between the two walk trials.

Figure 13 Tibialis Anterior Activity: Comparing the mean RMS of the anterior tibialis for all participants between walk one and two. The sEMG of the TA was significantly greater during the second walk compared to the first. Error bars = standard error of measurement. * =P < 0.05.

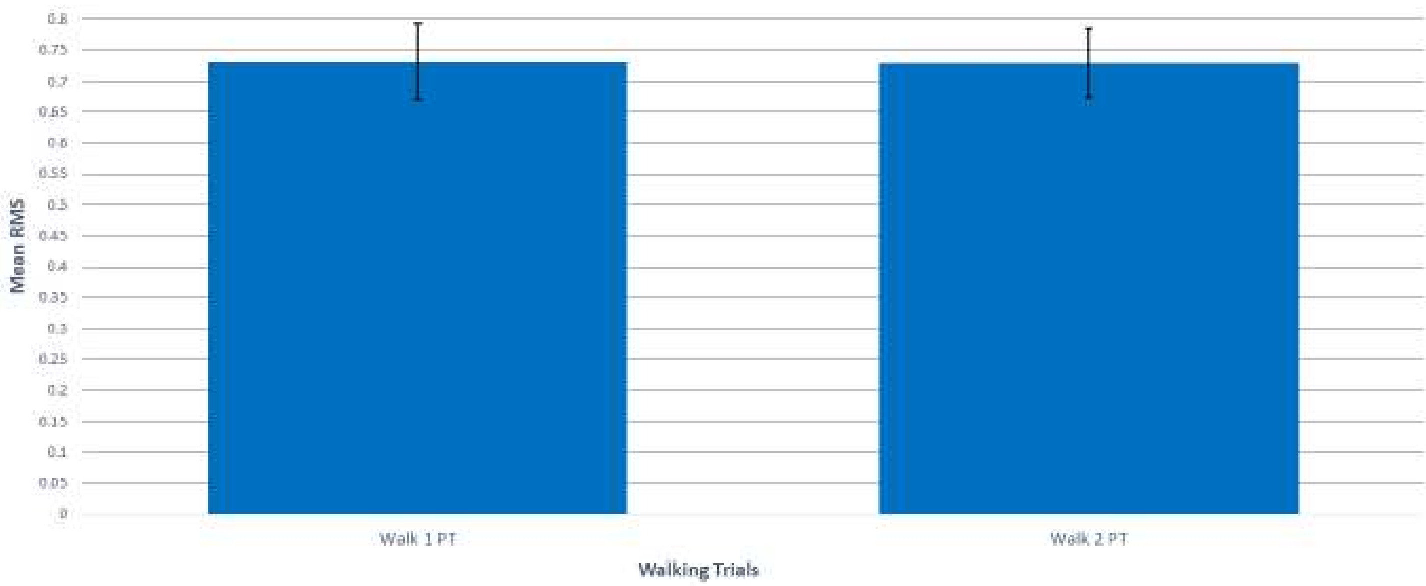


Figure 14 Posterior Tibialis Activity: Comparing the mean RMS of the posterior tibialis for all participants between walk one and two. The sEMG of the PT showed no difference between walk one and two. Error bars = standard error of measurement.

Figure 15 Peroneus Longus Activity: Comparing the mean RMS of the peroneus longus for all participants between walk one and two. The sEMG of the PL showed a trend towards greater activity during the second walk, P = 0.051. Error bars = standard error of measurement.

Figure 16 Soleus Activity: Comparing the mean RMS of the soleus for all participants between walk one and two. The sEMG of the SL showed no difference between walk one and two. Error bars = standard error of measurement.

CHAPTER 5

DISCUSSION

The purpose of this study was to identify differences in the sEMG activity of the anterior tibialis, fibularis longus, soleus, and posterior tibialis during Ebbets' foot drills compared to the normal gait cycle. The tibialis anterior showed more muscle activity during all Ebbets’ foot drills when compared to walking. The posterior tibialis showed greater muscle activity during three of Ebbets’ foot drills, walking on tiptoes pointed out, walking on tiptoes pointed in, and walking backward on tiptoes than normal walking. The peroneus (fibularis) longus showed greater muscle activity during these Ebbets’ foot drills, walking forwards on the heels, walking in eversion, walking on the tiptoes with toes pointed in and out, and walking on the tiptoes backward compared to normal walking. The results from this study supported hypothesis one fully about the tibialis anterior activity. Hypothesis two, about the posterior tibialis was accepted in part because no significant findings were found in two of the proposed drills, walking inversion and eversion. Hypothesis three about the peroneus longus was accepted in part because no significant findings were found in one of the proposed drills, walking in eversion. This study demonstrated Ebbets’ foot drills and the muscle activity of the lower leg during Ebbets’ foot drills and supported the hypotheses.

The sEMG for the tibialis anterior (TA) showed greater activity during all Ebbets' foot drill trials than the first walk trial (Figure 10). The greatest activity changes were seen in the first three drills, walking on the heels, walking on inversion, and walking in eversion. The tibialis anterior muscle function is dorsiflexion and assisting in inversion (Prentice, 2017). Walking on the heels requires the participants to hold their feet in dorsiflexion; walking in inversion requires the participants to walk with their foot in a maximal supinated position; supination involves inverting the foot. Walking in eversion requires the participant to walk with their foot in a maximally pronated position, and pronation involves dorsiflexing the foot. To hold the foot in all three of these positions while moving required great muscle activity, which was seen. In 2018 Bavdek investigated the lower leg muscles when walking on the regular ground and in various positions when walking on a 30° angled ramp (Bavdek et al., 2018). Bavdek found greater tibialis anterior activity when walking on the angled surface in FULL, walking with the whole foot touching the angled ramp, and LAT, walking the lateral edge of the foot off the angled ramp (Bavdek et al., 2018). Bavdek study contributed to increased muscle activity to the body, adapting to increasing stability, balance, and the stretch reflex from walking on the inclined ramp (Bavdek et al., 2018). While Ebbets' foot drills do not walk on an inclined ramp, walking in inversion (on the insides of the feet) and eversion (outsides of the feet) are very similar to Bavdek FULL and LAT positions. Bavdek FULL positions are like Ebbets' inversion position, and the LAT positions are similar to eversion. While these studies vary, observances can be made; healthy people put in obscure positions that challenge the body by putting the foot in positions of inversion and eversion resulted in an increase of sEMG activity of the tibialis anterior. Bavdek concluded that walking on the ramp may be an exercise that could strengthen the lower leg muscles but may be subject to habituation. While further research is needed, it could be speculated that the Ebbets' foot drills done during recovery from an injury could be beneficial.

The sEMG of the Posterior tibialis (PT) showed greater activity during the walking on tips toes toe-in, walking on tiptoes toe-out, and backward on tiptoe Ebbets' foot drills compared to Walk 1. The remaining Ebbets' foot drills, inversion, and eversion did not show greater activity (Figure 11). The tibialis posterior muscle function is inversion and assists with plantarflexion (Ivo Waerlop, 2016; Semple et al., 2009). The tiptoe drills with the toes pointed out, in, and then walking backward require the participant to hold their foot in a plantarflexed position while walking without falling, which required more muscle activity, as seen in the results. The literature reviewed found differences in the posterior tibialis during gait were not found in CAI studies but mainly in other diseases such as posterior tibial tendon dysfunction (PTTD) and rheumatoid arthritis-associated tenosynovitis (Barn et al., 2013; Ringleb et al., 2007). In the PTTD group compared to the control, the posterior tibialis was significantly greater during the stance phase and was contributed to the PTTD group posterior tibialis having to work harder to support the arch of the foot (Ringleb et al., 2007). Compared to the control, the RA group had higher EMG activity in the posterior tibialis and earlier onset times during the stance phase in the rheumatoid arthritis group. It was contributed to the group having to work harder to keep the arch's integrity even though they saw midfoot collapse during gait and help keep the foot's stability during the gait cycle (Barn et al., 2013). Varying alterations in muscle function of the posterior tibialis during gait have been seen in people with PTTD and tenosynovitis associated rheumatoid arthritis, because of the valgus deformity in the foot, while trying to maintain arch integrity, and for tenosynovitis RA because the mechanical alterations and the disease and weakness of the muscle to hold the arches (Barn et al., 2013; Ringleb et al., 2007). Three Ebbets' foot drills that involved walking on the toes increased the PT's activity; the posterior tibialis actions are inversion and assisting in plantarflexion; the constant holding of the foot in that position may be why walking on the toes in various positions increased the activity of the PT. One of the three articles Dr. Ebbets wrote about his drills is focused on the posterior tibialis (Ebbets, 2011b). Dr. Ebbets talked about how a lack of training and or upkeep of this muscle can lead to weakness. This will lead to varying problems such as shin splints, plantar fasciitis, achilles tendonitis, and may flatten the foot because of the weakness of the muscle and stretch of the plantar fascia (Ebbets, 2011b). Dr. Ebbets recommends that as a remedy and exercise to help avoid and fix these problems, the Ebbets' foot drills. This study found that the Ebbets' foot drills did affect the posterior tibialis, with significant findings in the last three drills that require walking on the tiptoes. While it is known in other injuries and diseases the musculature dysfunctional of posterior tibialis and its effects, it is also known that lateral ankle sprains can have a global impact on muscle function bilaterally in the lower extremity (Pietrosimone & Gribble, 2012; Webster et al., 2016). So, it may be possible that some of the effects seen in PTTD or tenosynovitis via RA or the varying possible issue that Dr. Ebbets listed in his article may be seen in people with LAS or CAI in the posterior tibialis as well, but more research focused on the PT in that population is needed to confirm this. What is known is that the posterior tibialis is affected by injury and has detrimental long-term effects. The study we conducted showed that Ebbets' foot drills can create significantly more muscle activity in the posterior tibialis than normal walking and can be used as an exercise to isolate and possibly strengthen the muscle.

The Peroneus longus (PL) sEMG showed greater activity during all the drills except the inversion drill compared to Walk 1. Walking in inversion may not have shown greater activity when compared to regular walking because of the overstretch put on the peroneus longus when in this position. The primary function performed by the fibularis (peroneus) longus is eversion, and it assists with plantarflexion; eccentrically, the muscle stabilizes supination of the ankle during activity and is essential for protection against lateral ankle sprains (Brockett & Chapman, 2016; Medina McKeon & Hoch, 2019). The peroneus longus eccentric control is important because a weak evertor such as the fibularis longus means a lack of control of supination, if someone gets into an injury-prone position, like the LAS mechanism, inversion with internal rotation (supination) with or without plantar flexion, and the muscles that cannot help protecting the joint because they are weak, more frequent injury may occur. During the drills, the greatest increases in muscle activity were seen during the eversion drill and the three drills required to walk on the tiptoes. The eversion drill required participants to hold their foot in a maximal everted and pronated positions while walking, which why this drill had a greater increase in muscle activity. When walking on the tiptoes with toes pointed inward, a plantarflexed position while stabilizing the ankle so it would not collapse because of this high-risk injury-prone position is why this drill had a greater increase in muscle activity. When walking on the tiptoes with toes pointed out, this required participants to hold their foot in a plantarflexed and everted positions while walking and is why a greater increase in muscle activity was seen. Walking backward on the tiptoes, participants had to hold themselves in a plantarflexed position while stabilizing themselves not to fall, which required greater muscle activity. In the 2018 Bavdek angled ramp study, healthy participants showed greater activity of the fibularis (peroneus) longus during FULL and LAT walking than normal walking; the reason given for the increase in muscle activity was an increase in stability to prevent collapse during challenging gait (Bavdek et al., 2018). The same could be said about Ebbets' foot drills; looking at the fibularis longus, all but one drill caused increased muscle activity; Ebbets' foot drills are challenging gait tasks, increasing muscle activity to increase the stability of the muscles the ankle joint and prevent collapse during gait. The fibularis longus has shown altered activity in injured ankles. During gait assessment, it was found the CAI group had greater fibularis longus activity during the heel strike phase compared to the healthy group, but less activity during early and midstance with earlier onset and longer activation times compared to the healthy group (Delahunt et al., 2006;

Feger et al., 2015; Son et al., 2019). The feedforward mechanism explained more activity during the heel strike phase, the affected area working harder to plan out a functional task (Delahunt et al., 2006). Less activity was explained by altered biomechanics, which leads to less dynamic stability (Son et al., 2019). While more research is needed to confirm, it has been seen in this study that Ebbets' foot drills challenge the muscles during gait by demanding an increase in dynamic stability. It may be possible that Ebbets' foot drills could help restore some dynamic stability in acute and or chronic ankle injuries.

A statistical finding to bring to attention was the activity of the soleus during the drills. While not hypothesized, one of the soleus reasons during this experiment was to help validate sEMG collection for the location used for the PT, while because of its location and function to see if any changes in muscle activity occurred. Unexpectedly, the soleus (SL) sEMG showed greater activity during all the walking drills than Walk 1, and the drills' main effect on the SL was statistically significant. In this study, the primary purpose of the sEMG of the soleus was to verify if the sEMG of the posterior tibialis was being collected. During both analyses of gait and strength measurements, two distinct signals were collected. Most research done on the injured ankle did not usually select the soleus for their studies; the gastrocnemius was often preferred. The literature reviewed found a study looking at muscle activity between people with chronic ankle instability and a healthy control assess the soleus muscle activity. In 2006 Delahunt et al. assessed kinematic and electromyography during barefoot walking on a treadmill. The results concluded that there were no significant differences between the CAI group and the control group with the soleus's activity (Delahunt et al., 2006). Those results could mean that the soleus is not a muscle affected globally from injury in its function or that perhaps this study controlled the treadmill speed and grade. There was not enough intensity to see a difference. More research should include the soleus in ankle studies to see how they are not affected by either conclusion. Bavdek's angled ramp study included the soleus and gastrocnemius, and in the discussion, it is explained that of all the plantar flexors recorded in the study, the most active was the soleus (Bavdek et al., 2018). That means between walking FULL (whole foot touching the ramp) and LAT (just the medial part of the foot touching the ramp), the soleus was the most active plantar flexor during those walks (Bavdek et al., 2018). While the soleus was most active in normal walking, it cannot be ignored that the soleus may play some role instability when walking on the angled ramp. While Ebbets' foot drills are done on the ground or floor, some of Ebbets' foot drills are in a similar position as the angled ramp, and depending on the participant during Ebbets' foot drills, they may have exceeded the 30 degrees that Bavdek angled ramp was set at, especially when walking in inversion. In this study, the soleus was more active during all Ebbets' foot drills than normal walking. This finding about the soleus was not hypothesized due to the original reasoning for the soleus sEMG. The results showed that Ebbets' foot drills challenged the soleus muscle, which could help build onto Bavdek observation and other studies that the triceps surae complex may play a role in stability (Bavdek et al., 2018). This study on Ebbets' foot drills gave information on how the soleus reacts in drills that require dynamic stability to perform and complete in healthy individuals. This finding also confirms that these drills focus on each muscle compartment (anterior, lateral, superficial, and deep posterior) of the lower leg. While more research will be needed to see how it acts on each lower leg muscle, this study is the first step.

These findings reveal the muscles activity during Ebbets’ foot drills vs. normal gait are crucial to the study because they answer the research question, will the activity of the tibialis anterior, fibularis longus, soleus, and posterior tibialis during Ebbets' foot drills differ from the muscle activity during a normal gait? The results gave the answers of what the muscles' sEMG activity during the drills is, and that overall, the muscles activity differed between the drills and normal walking. These findings build evidence about Dr. Ebbets claims about the drills and their use. The Ebbets' foot drills can increase the strength of the lower leg musculature. These results have given the ground information of what the drills do to the muscles and can be a starting point for future research. The high prevalence of LAS (Doherty et al., 2014), along with the high rate of re-injury (Yeung et al., 1994), and the risk of developing CAI following LAS (Delahunt & Remus, 2019) still call for an improved understanding of the methods used to prevent LAS and rehabilitate the patient with LAS. This study's results have opened an avenue for rehabilitation and prevention of LAS and some of the adverse effects seen in people who develop CAI, weakness, neuromuscular alterations, and fatigue.

These results have started supporting Ebbets' foot drills and are a beginning point to provide evidence of their use. As know from the 2016 ankle consortium, LAS should be treated as a severe orthopedic injury, and CAI is a debilitating and degenerative condition with long-term effects (Gribble et al., 2016). Even with updated methods of understanding on ankle injuries, treatment and rehabilitation, protocols vary, and LAS injury and recurrence are still high and with the building of evidence of more people not getting treated. Ebbets' foot drills with more research could become a versatile piece for rehabilitation and treatment. Healthcare professionals want to find the best evidence-based practices for their patients to provide the best healthcare. Before Ebbets' foot drills, evidence for use was anecdotal, but with this beginning evidence, they can now be looked for their use in the treatment and rehabilitation of LAS, CAI, and its long-term effects.

A few things were not hypothesized or did not make statistical significance but are worth mentioning. After data analysis, when comparing Walk one vs. walk two, during walk two, the tibialis anterior had statistically significant (P=0.032) greater muscle activity than Walk 1. This significant finding is important because this showed that in the study conducted, Ebbets' foot drills had an acute effect on the tibialis muscle activity, further providing evidence of the drills' daily use. The peroneus longus showed a trend (P=0.051) for greater activity during walk two than walk one. This trend is worth mentioning because of the importance of the peroneus longus for ankle injury and injury prevention. This trend alludes to in theory that there could be an acute effect of Ebbets' foot drills that activate the fibularis longus, increasing the ankle's stabilization. However, more research with significant findings would be needed to confirm this. These findings are essential because Dr. Ebbets reasoning for the drills is that using them daily will strengthen the muscles, the neural pathway and reduce injuries. Comparing walks gives insight into using these drills and the acute effects of muscle activity after the drills. The changes seen in the tibialis anterior and trend in the peroneus longus help support Dr. Ebbets' reasoning that doing these drills induce changes that benefit the participant.

Limitations

The study's limitations include variability in athletic ability, sample size, drill familiarity, and a single person who was excluded. The athletic ability or aptitude to perform a new task varies among people. At the same time, age, health standard, and sport limitations were controlled; the athletic ability could not be controlled because of the varying levels of people's athletic ability; this affected strength measurements and the SEBT results. Another limitation is that this sample group was not random but selected at a convenience sample of people who qualified and were willing to participate in the study and finishing with a smaller sample size of 21 but with significant power. The Ebbets' foot drills' familiarity was another limitation to this study; previously, before coming into the lab for data collection, Ebbets' foot drills were unheard of to most participants. While most things have a learning curve, the participant did not have that time but performed the drills to the best of their ability in their limited time knowing the drills. Another limitation was that the participants did not wear shoes. In the article, the drills described by Dr. Ebbets walking forwards on the heels were always in shoes because of the Ebbets' foot drills daily use to prevent heel bruising, but for consistency of the drills through the protocol, all drills were done without shoes. A final limitation was having to exclude one of our participants who originally met all criteria to participate in the study, but during strength, testing was having pains in the knee and the ankle. This patient did have a history of previous ankle injuries but none in the last year, and no fractures or surgery required. They also did not show any alarming signs during IDFAI or the FAAM.

Future Research

Future research could expand in a few ways. First looking at Ebbets' foot drills and muscle activity of the drills in a healthy population and chronic ankle instability population, an added step to that could be to note the changes of both populations over time. Another study could be to add in collecting timing of the gait cycle off while collecting sEMG and looking at when the muscles onset and offset times throughout the gait cycle. Next, a study that would follow the effects of the drills, if an acute bout would change on and offset times of the muscles, joint positioning, muscle activation, and neuromuscular control. Doing the drills but with indwelling EMG for the posterior tibialis and or all the muscles. A study looking at the muscle activity during Ebbets' foot drills in a healthy population over time as you teach them the drills, follow them, and see if the drills are used for prevention. Dr. Ebbets claims the Ebbets' foot drills can be used for strengthening the muscles, but what about those who have become injured? Another study could look at the muscle activity during Ebbets' foot drills with a chronic ankle instability population and see if the drills could reduce injury. A study looks at people recovering from an acute LAS and how they heal how the muscle activity changes. Acute LAS, Copers, and people with CAI have all shown alterations in muscle function such as onset times and varying activation during the gait cycle (Doherty et al., 2015; Feger et al., 2015). In the future, longer research clinical trials should follow healthy people, people with acute LAS, and CAI to note differences over time using the drills. Following the mechanoreceptor, theory walking in the drills while wearing shoes and not wearing shoes (Dingenen et al., 2015). Another path that could be taken is using the Ebbets' foot drills before activity vs. after activity. Another avenue that should be taken is looking at the drills' acute effects, as seen with data analysis when comparing walk one vs. walk two. Using EMG to measure balance, strength, walking, or another task of daily living, complete Ebbets' foot drills and repeat those measures to see the acute effects the drills have on the muscles.

Conclusion

Ebbets' foot drills have shown that they generate greater muscle activity than regular walking in a single bout of exercise, which means the drills have use in strengthening the tibialis anterior, peroneus longus, tibialis posterior, and soleus. The drills also have shown an acute effect and trends on the muscles on normal walking after a single bout of the drills. This evidence starts to help prove Dr. Ebbets claims of using these drills for strengthening, increasing stability, neuromuscular efficiency, and injury prevention. As further research continues, the theory and use of these may be supported with more evidence.

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APPENDIX I

IRB APPROVAL

MARSHALL UNIVERSITY

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Office of Research Integrity
Institutional Review Board
One John Marshall Drive
Huntington, WV 25755

FWA 00002704

IRB1 #00002205
IRB2 #00003206

January 21, 2020

Mark Timmons, PhD
School of Kinesiology, Marshall University

RE: IRBNet ID# 1545872-1
At: Marshall University Institutional Review Board #1 (Medical)

Dear Dr. Timmons:

Protocol Title:	[1545872-1] Ankle Muscle Activation and Mechanics during Ebbets' Ankle Drills	
Site Location:	MU	
Submission Type:	New Project	APPROVED
Review Type:	Expedited Review	

In accordance with 45CFR46.110(a)(4) and (7), the above study was granted Expedited approval today by the Marshall University Institutional Review Board #1 (Medical) Chair. An annual update will be required on January 21, 2021 for administrative review and approval. The update must include the Annual Update Form and current educational certificates for all investigators involved in the study. All amendments must be submitted for approval by the IRB Chair prior to implementation and a closure request is required upon completion of the study.

This study is for student Quentin Archuleta.

If you have any questions, please contact the Marshall University Institutional Review Board #1 (Medical) Coordinator Margaret Hardy at (304) 696-6322 or hardyma@marshall.edu. Please include your study title and reference number in all correspondence with this office.

Sincerely,

Bruce F. Day, ThD, CIP
Director, Office of Research Integrity

- 1 -

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APPENDIX II

INFORMED CONSENT

Informed Consent to Participate in a Research Study

Ankle Muscle Activation and Mechanics during Ebbets' Ankle Drills

Mark Timmons PhD, Principal Investigator

Marshall University IRB

Approved on:	1/21/20
Study number:	1545872

Key Information

You are invited to participate in a research study. Research studies are designed to gain scientific knowledge that may help other people in the future. You may or may not receive any benefit from being part of the study. Your participation is voluntary. Please take your time to make your decision, and ask your research investigator or research staff to explain any words or information that you do not understand. The following is a short summary to help you decide why you may or may not want to be a part of this study. Information that is more detailed is listed later on in this form.

The purpose of the study is to determine the activity of the lower leg muscles during the exercises used to prevent ankle injuries. You will be asked to perform several contractions of your lower leg muscles and to walk 25 yards 8 times. We expect that you will be in this research study for one testing session of about 1.5 hours duration. The primary risk of participation is that the muscle of your lower leg might become fatigued.

How Many People Will Take Part In The Study?

About 30 people will take part in this study. A total of 40 subjects are the most that would be able to enter the study.

What Is Involved In This Research Study?

You will be asked to complete several forms asking for information about your ankle function and injury history. The researchers will perform several tests to determine stability and strength of your ankles. Then small sensors will be applied to your lower leg, these sensors are attached with adhesive tape. After the sensors are in place, you will perform several maximal contractions of your lower leg muscle with your ankle in different positions. You will then perform 8 walking trials. During each trial, you will walk 25 yards with your feet in differing positions. You will be given specific directions on how to position your feet and be allowed to practice each positon prior to data collection. You will be given about a 5-minute rest between trials. Following the walking trials, the sensors will be removed, and you will be done with the testing.

What about Alternative Procedures?

There are no alternative procedures to this investigation; you do not have to participate in this study.

What Are Your Rights As A Research Study Participant?

You may choose not to take part, or you may leave the study at any time. Refusing to participate or leaving the study will not result in any penalty or loss of benefits to which you are entitled. If you

Subject's Initials ________

decide to stop participating in the study, we encourage you to talk to the investigators or study staff first.

The study investigator may stop you from taking part in this study at any time if he/she believes it is in your best interest; if you do not follow the study rules; or if the study is stopped.

Detailed Risks of the Study

You might experience fatigue of your leg muscles during the testing this fatigue feeling might last for a few hours following the testing. The feeling will be similar to the feelings you experience during exercise or prolonged walking. The sensors will be held in place with adhesive tape similar to the tape used to hold band aids in place. A few people might develop a mild allergic reaction to the tape.

What About Confidentiality?

We will do our best to make sure that your personal information is kept confidential. However, we cannot guarantee absolute confidentiality. Federal law says we must keep your study records private. Nevertheless, under unforeseen and rare circumstances, we may be required by law to allow certain agencies to view your records. Those agencies would include the Marshall University IRB, Office of Research Integrity (ORI) and the federal Office of Human Research Protection (OHRP). This is to make sure that we are protecting your rights and your safety. If we publish the information, we learn from this study, you will not be identified by name or in any other way.

What Are The Costs Of Taking Part In This Study?

There are no costs to you for taking part in this study. All the study costs, including any study tests, supplies and procedures related directly to the study, will be paid for by the study.

Will You Be Paid For Participating?

You will receive no payment or other compensation for taking part in this study.

Whom Do You Call If You Have Questions Or Problems?

For questions about the study or in the event of a research-related injury, contact the study investigator, **Mark Timmons ATC PhD at (304) 696-2925**. You should also call the investigator if you have a concern or complaint about the research.

For questions about your rights as a research participant, contact the Marshall University Office of Research Integrity (ORI) at (304) 696-4303. You may also call this number if:

- You have concerns or complaints about the research.
- The research staff cannot be reached.
- You want to talk to someone other than the research staff.

You will be given a signed and dated copy of this consent form.

Subject's Initials ________

SIGNATURES

You agree to take part in this study and confirm that you are 18 years of age or older. You have had a chance to ask questions about being in this study and have had those questions answered. By signing this consent form, you are not giving up any legal rights to which you are entitled.

____
Subject Name (Printed)

______________________________ ____________
Subject Signature Date

____
Person Obtaining Consent (Printed)

______________________________ ____________
Person Obtaining Consent Signature Date

Subject's Initials ________

APPENDIX III

DATA COLLECTION FORM

Subject ID number: ____________________ **Date: ___/___/___**

Data Collection Forms

Ankle Muscle Activation and Mechanics during Ebbets' Ankle Drills

Procedure Checklist

1. Inclusion & exclusion criteria
   a. Eligibility Screening exam
2. Subject Informed Consent
   a. Read, discuss, ask questions, sign
3. General Questions- Eligibility and Screening
   a. Intake information
   b. Patient reported outcomes (FAAM, IdFAI)
   c. Physical activity assessment
4. Height , Weight
5. Clinical Evaluation
6. Strength Procedure
   a. Inversion, Eversion, Plantar flexion, Dorsiflexion
7. EMG electrode placement
   a. Anterior Tibalis
   b. Posterior Tibalis
   c. Soleus
   d. Fibularis Longus
8. EMG normalization procedure
9. Ebbets' Ankle Drills

Inclusion criteria:

1. Lower extremity pain during gait $\leq$ 2/10
2. Unrestricted foot and ankle motion
3. At least 18 and < 30 years of age

Exclusion criteria (any 1 excludes):

1. Low Back pain $\geq$2/10
2. History of lower leg, ankle or foot fracture
3. Participant reported episode of ankle instability or "giving out" (<2 episodes in past 6 months)
3. Systemic musculoskeletal disease
4. Ankle or foot surgery
5. Lower extremity pain $\geq$2/10
6. Evidence of acute ankle injury
7. Evidence of chronic ankle instability (FAAM ADL <90%, FAAM Sport < 80%, IdFAI > 10)

Subject meets inclusion/exclusion criteria (circle one):

Page 1 of 6

Subject ID number: ____________________ **Date:** ___/___/___

1= Yes, continue 2= No, stop

Research Study Questionnaire
Participant completes:

DOB (mm/dd/yy): ___/__/___

Age: ____ (years) **Sex:** 1 = Female 2 = Male

1. **Do you have any systemic musculoskeletal disease (like Rheumatoid Arthritis)?**

   (Circle One) 1 = Yes If yes, please list________________________
   2 = No

2. **Do you currently have lower extremity pain or have had lower extremity pain in the last 6 months?**

   (Circle One) 1 = Yes 2 = No

   If yes, how would you rate the pain?
   (0 = no pain at all, 10 = the worst imaginable pain) ___________

3. **Do you currently have low back pain pain or have had low back pain in the last 6 months?**

   (Circle One) 1 = Yes 2 = No

   If yes, how would you rate the pain?

   (0 = no pain at all, 10 = the worst imaginable pain) ___________

4. **What is your dominant side?** Which hand do you use to write or throw a ball?

   1 = Right
   2 = Left
   3 = Ambidextrous

5. **How would you rate your ankle today (as "a percentage of normal")?**

   (0% - 100% with 100% being normal) = ______**%**

6. **Have you had ankle or foot surgery?**

   1 = Yes 2 = No

7. **Do you have a known lower leg, ankle, or foot problem/ pathology?**

   1 = Yes   2 = No

   a. If yes, which lower leg, foot or ankle?

      1 = Right   2 = Left   3= Both

   b. If yes, have you sought treatment for this problem

      1 = Yes   2 = No

   c. If yes, when did your ankle / foot pain start?
      1 ____ Less than 6 weeks ago
      2 ____ 6-12 weeks ago
      3 ____ More than 12+ weeks ago
      4 ____ I do not have shoulder pain

   d. If yes, please describe: ____

8. Has your ankle ever given out while walking or during physical activity?

   a) If yes, which ankle?

      1 = Right   2 = Left   3= Both

   b) If yes, how many times has your ankle "given out" in the past 6 months? _______

Subject ID number: ____________________ **Date:** ___/___/___

IDENTIFICATION OF FUNCTIONAL ANKLE INSTABILITY (IdFAI)

Instructions: This form will be used to categorize your ankle stability status. A separate form should be used for the right and left ankles. Please fill out the form completely and if you have any questions, please ask the administrator. Thank you for your participation.

Please carefully read the following statement:
"Giving way" is described as a temporary uncontrollable sensation of instability or rolling over of one's ankle.

I am completing this form for my **RIGHT/LEFT** ankle (circle one).

1.) Approximately how many times have you sprained your ankle? ________

2.) When was the last time you sprained your ankle?

▯ Never	▯ > 2 years	▯ 1-2 years	▯ 6-12 months	▯ 1-6 months	▯ < 1 month
0	1	2	3	4	5

3.) If you have seen an athletic trainer, physician, or healthcare provider how did he/she categorize your most serious ankle sprain?

▯ Have **not** seen someone	▯ Mild (Grade I)	▯ Moderate (Grade II)	▯ Severe (Grade III)
0	1	2	3

4.) If you have ever used crutches, or other device, due to an ankle sprain how long did you use it?

▯ Never used a device	▯ 1-3 days	▯ 4-7 days	▯ 1-2 weeks	▯ 2-3 weeks	▯ >3 weeks
0	1	2	3	4	5

5.) When was the last time you had *"giving way"* in your ankle?

▯ Never	▯ > 2 years	▯ 1-2 years	▯ 6-12 months	▯ 1-6 months	▯ < 1 month
0	1	2	3	4	5

6.) How often does the ***"giving way"*** sensation occur in your ankle?

▯ Never	▯ Once a year	▯ Once a month	▯ Once a week	▯ Once a day
0	1	2	3	4

7.) Typically when you start to roll over (or 'twist') on your ankle can you stop it?

▯ Never rolled over	▯ Immediately	▯ Sometimes	▯ Unable to stop it
0	1	2	3

8.) Following a typical incident of your ankle rolling over, how soon does it return to 'normal'?

▯ Never rolled over	▯ Immediately	▯ < 1 day	▯ 1-2 days	▯ > 2 days
0	1	2	3	4

9.) During "Activities of daily life" how often does your ankle feel ***UNSTABLE?***

▯ Never	▯ Once a year	▯ Once a month	▯ Once a week	▯ Once a day
0	1	2	3	4

10.) During "Sport/or recreational activities" how often does your ankle feel ***UNSTABLE?***

▯ Never	▯ Once a year	▯ Once a month	▯ Once a week	▯ Once a day
0	1	2	3	4

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Screening Exam
Research Team completes

Stop Here. Remainder to be completed by study personnel. Thank you.

Subject height:

Subject ID number: ____________________ **Date:** ___/___/___

__________(cm) **Subject weight:**______________(Kg)

ROM:

	Right	Left
IN	________	________
EV	________	________
PF	________	________
DF	________	________
Gr Toe F	________	________
Gr Toe E	________	________

Arch type

Right foot	pes cavus	pes rectus	pes planus
Left foot	pes cavus	pes rectus	pes planus

Posterior foot type

Right foot	supinated	neutral	pronated
Left foot	supinated	neutral	pronated

	Right Leg	Left Leg
Leg Length	________	________

Single Leg Balance Test

Right Leg	Left Leg
________	________

Star Excursion Balance Test

	Right Stance Leg	Left Stance Leg
Anterior	________	________
Post Med	________	________
Post Lat	________	________

Special Tests:	Right ankle		Left ankle	
Anterior Draw	+	-	+	-
Talar Tilt	+	-	+	-
Compression test	+	-	+	-
ATF pain	+	-	+	-
CF pain	+	-	+	-
Sinus Tarsi pain	+	-	+	-

Page 5 of 6

Subject ID number: ____________________ **Date: ___/___/___**

Force, Pain and Scapular Position

Trial	Pain (0-10)	Force (lbs.)
EV 1		
IV 1		
PF 1		
DF 1		
EV 2		
IV 2		
PF 2		
DF 2		
EV 3		
IV 3		
PF 3		
DF 3		

APPENDIX IV

FAAM

Foot and Ankle Ability Measure (FAAM)
Activities of Daily Living Subscale

Please Answer **every question** with **one response** that most closely describes your condition within the past week.
If the activity in question is limited by something other than your foot or ankle mark "Not Applicable" (N/A).

	No Difficulty	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Standing	□	□	□	□	□	□
Walking on even Ground	□	□	□	□	□	□
Walking on even ground without shoes	□	□	□	□	□	□
Walking up hills	□	□	□	□	□	□
Walking down hills	□	□	□	□	□	□
Going up stairs	□	□	□	□	□	□
Going down stairs	□	□	□	□	□	□
Walking on uneven ground	□	□	□	□	□	□
Stepping up and down curbs	□	□	□	□	□	□
Squatting	□	□	□	□	□	□
Coming up on your toes	□	□	□	□	□	□
Walking initially	□	□	□	□	□	□
Walking 5 minutes or less	□	□	□	□	□	□
Walking approximately 10 minutes	□	□	□	□	□	□
Walking 15 minutes or greater	□	□	□	□	□	□

Foot and Ankle Ability Measure (FAAM)
Activities of Daily Living Subscale
Page 2

Because of your foot and ankle how much difficulty do you have with:

	No Difficulty at all	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Home responsibilities	☐	☐	☐	☐	☐	☐
Activities of daily living	☐	☐	☐	☐	☐	☐
Personal care	☐	☐	☐	☐	☐	☐
Light to moderate work (standing, walking)	☐	☐	☐	☐	☐	☐
Heavy work (push/pulling, climbing, carrying)	☐	☐	☐	☐	☐	☐
Recreational activities	☐	☐	☐	☐	☐	☐

How would you rate your current level of function during you usual activities of daily living from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities.

__ __ __ . 0 %

Martin, R; Irrgang, J; Burdett, R; Conti, S; VanSwearingen, J: Evidence of Validity for the Foot and Ankle Ability Measure. Foot and Ankle International. Vol.26, No.11: 968-983, 2005.

Foot and Ankle Ability Measure (FAAM)
Sports Subscale

Because of your foot and ankle how much difficulty do you have with:

	No Difficulty at all	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Running	☐	☐	☐	☐	☐	☐
Jumping	☐	☐	☐	☐	☐	☐
Landing	☐	☐	☐	☐	☐	☐
Starting and stopping quickly	☐	☐	☐	☐	☐	☐
Cutting/lateral Movements	☐	☐	☐	☐	☐	☐
Ability to perform Activity with your Normal technique	☐	☐	☐	☐	☐	☐
Ability to participate In your desired sport As long as you like	☐	☐	☐	☐	☐	☐

How would you rate your current level of function during your sports related activities from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities?

__ __ __ . 0%

Overall, how would you rate your current level of function?

☐ Normal ☐ Nearly Normal ☐ Abnormal ☐ Severely Abnormal

Martin, R; Irrgang, J; Burdett, R; Conti, S; VanSwearingen, J: Evidence of Validity for the Foot and Ankle Ability Measure. Foot and Ankle International. Vol.26, No.11: 968-983, 2005.

APPENDIX V

IDFAI

IDENTIFICATION OF FUNCTIONAL ANKLE INSTABILITY (IdFAI)

Instructions: This form will be used to categorize your ankle stability status. A separate form should be used for the right and left ankles. Please fill out the form completely and if you have any questions, please ask the administrator. Thank you for your participation.

Please carefully read the following statement:
"Giving way" is described as a temporary uncontrollable sensation of instability or rolling over of one's ankle.

I am completing this form for my **RIGHT/LEFT** ankle (circle one).

1.) Approximately how many times have you sprained your ankle? ________

2.) When was the last time you sprained your ankle?

☐ Never	☐ > 2 years	☐ 1-2 years	☐ 6-12 months	☐ 1-6 months	☐ < 1 month
0	1	2	3	4	5

3.) If you have seen an athletic trainer, physician, or healthcare provider how did he/she categorize your most serious ankle sprain?

☐ Have <u>not</u> seen someone	☐ Mild (Grade I)	☐ Moderate (Grade II)	☐ Severe (Grade III)
0	1	2	3

4.) If you have ever used crutches, or other device, due to an ankle sprain how long did you use it?

☐ Never used a device	☐ 1-3 days	☐ 4-7 days	☐ 1-2 weeks	☐ 2-3 weeks	☐ >3 weeks
0	1	2	3	4	5

5.) When was the last time you had *"giving way"* in your ankle?

☐ Never	☐ > 2 years	☐ 1-2 years	☐ 6-12 months	☐ 1-6 months	☐ < 1 month
0	1	2	3	4	5

6.) How often does the *"giving way"* sensation occur in your ankle?

☐ Never	☐ Once a year	☐ Once a month	☐ Once a week	☐ Once a day
0	1	2	3	4

7.) Typically when you start to roll over (or "twist") on your ankle can you stop it?

☐ Never rolled over	☐ Immediately	☐ Sometimes	☐ Unable to stop it
0	1	2	3

8.) Following a typical incident of your ankle rolling over, how soon does it return to "normal"?

☐ Never rolled over	☐ Immediately	☐ < 1 day	☐ 1-2 days	☐ > 2 days
0	1	2	3	4

9.) During "Activities of daily life" how often does your ankle feel ***UNSTABLE***?

☐ Never	☐ Once a year	☐ Once a month	☐ Once a week	☐ Once a day
0	1	2	3	4

10.) During "Sport/or recreational activities" how often does your ankle feel ***UNSTABLE***?

☐ Never	☐ Once a year	☐ Once a month	☐ Once a week	☐ Once a day
0	1	2	3	4

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1

Figure 1. The Identification of Functional Ankle Instability (IdFAI) questionnaire, including scoring rubric.
Reprinted with permission from Simon J, Donahue M, Docherty C. Development of the Identification of Functional Ankle Instability (IdFAI). *Foot & Ankle International.* 33(9):755-763, © 2012 by the American Orthopaedic Foot and Ankle Society, Inc.

2 points. An additional 13 (11.8%) participants differed by 3 points, 6 (5.5%) by 4 points, and 1 (0.91%) by 10 points. A Bland-Altman plot indicates that reliability of the IdFAI score did not change systematically (Figure 2).

Validity

A statistically significant correlation was noted between the LEFS and the IdFAI ($\rho = -0.38$, $P < .01$) (Table 2). The correlations between the LEFS and history and initial ankle sprain factors on the IdFAI were