KINETIC AND KINEMATIC DIFFERENCES IN EXPECTED AND UNEXPECTED DROP LANDING ANKLE INVERSION

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This thesis entitled
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DROP LANDING ANKLE INVERSION

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Abstract

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KINETIC AND KINEMATIC DIFFERENCES IN EXPECTED AND UNEXPECTED DROP LANDING ANKLE INVERSION (76 pp.)

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Ankle inversion studies have utilized various inversion platforms and EMG analysis. Studies are needed that better describe the kinetics and kinematics of these dynamic inversion moments. A MANOVA was used to analyze the kinetics and kinematics of expected and unexpected single leg drop landing ankle inversion. Twenty centimeter single leg drop landing trials were randomized between a flat surface or 30° inversion wedge. After each trial, subjects reported whether the surface was expected or unexpected. Each subject repeated trials until four expected and four unexpected trials onto the inversion wedge were recorded. Kinetics and kinematics were described by analyzing vertical ground reaction force (VGRF), electromyography (EMG), and 2D motion analysis. Data was collected for maximum ankle inversion, maximum inversion velocity, peak EMG, maximum VGRF, time from contact to: maximum ankle inversion, peak EMG, and maximum VGRF, and time from maximum ankle inversion to peak EMG, time from maximum VGRF to peak EMG were recorded.

Approved:

Jeffrey G. Seegmiller

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Introduction

Inversion injuries to the ankle complex are arguably the most common injury in athletics. Soboroff, Pappius and Komaroff (1984) reported that more than two million people are affected by ankle injuries in the United States every year. This high incidence of ankle injury has led to a wide variety of research regarding the ankle and its supporting structures. The focus areas include the effects of prophylactic taping and/or bracing on ankle range of motion and peroneal reaction times. However there is still a void in the literature regarding drop landings onto inverted surfaces and separating inversion trials between expected and unexpected landings.

Research that involves rapid tilting inversion platforms and different variables such as prophylactic taping, bracing, and peroneal reaction times has been well documented. Adhesive tape has been shown to decrease range of motion, inversion velocity, and time to total inversion (Ashton-Miller, Hutchinson, & Wojtys, 1996; Konradsen, 2002; and Olmsted, Vela, Denegar, & Hertel, 2004). The effects of prophylactic bracing are also well known. In the literature it has been reported that bracing decreases ankle range of motion as well as prophylactic ankle taping (Cordova, Ingersoll, & LeBlanc, 2000; Cordova, Ingersoll, Palmieri, 2002; Olmsted, et al. 2004; and Verhagen, van der Beek, & van Mechelen, 2001). One benefit bracing has over tape is that the effects of bracing have been shown to last longer than that of tape (Cordova, et al. 2000; Cordova, et al. 2002; and Verhagen, et al. 2001).
Peroneal reaction times have also been studied extensively. The effects of different variables such as ankle bracing (Konradsen, Peura, Beynnon, & Renstrom, 2005), instability (Ebig, Lephart, Burdett, Miller, & Pincivero, 1997; Rosenbaum, Becker, Gerngro, & Claes, 2000; Vaes, Duquet, & Van Gheluwe, 2002), and surgery (Johnson & Johnson, 1993) have been previously studied. Peroneal reaction during dynamic ankle inversion has been studied extensively because the pre-activated peroneal muscle group has been shown to be the best provider of dynamic stability in the ankle (Ashton-Miller, et al. 1996). The results of these peroneal reaction time studies vary widely. Each study has slightly different procedures and criteria for analyzing the raw data, which might be the cause of these variances. Konradsen (2002) reviewed research that reported peroneal reaction times and observed that peroneal reaction times range from 49 milliseconds (ms) to 90 ms.

Previous scientific research on ankle inversion, inversion platforms, and drop landings onto an inverted surface have not separated data into expected or unexpected trials. Therefore, this thesis separates expected dynamic inversion moments of a single leg drop landing from those that are unexpected and compares vertical ground reaction forces during each. To collect this data, a single leg drop landing was performed onto an inverted surface positioned in the middle of a force plate. Two dimensional (2D) motion analysis and electromyography (EMG) of the peroneus longus were also examined. The purpose of this study was to compare kinetic and kinematic data of an expected landing onto an inverted surface to an unexpected landing onto an inverted surface. I hypothesize that subjects will experience greater ankle inversion, greater inversion velocity, greater
peak EMG, increased ground reaction force, and larger delay to peak EMG in unexpected landings than in expected landings.

Statement of the Problem

Scientific research regarding the kinematics and kinetics of expected and unexpected drop landing ankle inversion is not well documented. Therefore, this research specifically examines the following questions:

1. Is there a difference in the amount of ankle inversion between expected and unexpected drop landings?
2. Is there a difference in inversion velocity between expected and unexpected drop landings?
3. Is there a difference in peak EMG between expected and unexpected drop landings on an inverted surface?
4. Is there a difference in number of body weights between expected and unexpected drop landings on an inverted surface?
5. Is there a difference in the amount of time from toe contact to maximum ankle inversion between expected and unexpected drop landings?
6. Is there a difference in the amount of time from toe contact to peak EMG between expected and unexpected drop landings on an inverted surface?
7. Is there a difference in the amount of time from toe contact to maximum vertical ground reaction force between expected and unexpected drop landings on an inverted surface?
8. Is there a difference in the amount of time from peak EMG to maximum ankle inversion between expected and unexpected drop landings?

9. Is there a difference in the amount of time from maximum vertical ground reaction force to peak EMG between expected and unexpected drop landings on an inverted surface?

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16. Is there a difference in the amount of time from toe contact to maximum vertical ground reaction force between male and female drop landings on an inverted surface?

17. Is there a difference in the amount of time from peak EMG to maximum ankle inversion between male and female drop landings?
18. Is there a difference in the amount of time from maximum vertical ground reaction force to peak EMG between male and female drop landings on an inverted surface?

Purpose of the Study

This thesis compares the kinetics and kinematics of expected and unexpected drop landings onto an inverted surface. Specifically, this thesis was designed to compare the amount of ankle inversion, inversion velocity, EMG activity of the peroneus longus muscle, vertical ground reaction force and different times between each of the previously mentioned variables. Gender comparisons were a focus of this thesis between these variables. This thesis separates trials into expected and unexpected groups and compares vertical ground reaction forces during a dynamic single leg drop landing inversion moment.

Null Hypothesis

H\textsubscript{01}: There is no significant difference between the expected and unexpected groups in maximum ankle inversion.

H\textsubscript{02}: There is no significant difference between the expected and unexpected groups in maximum ankle inversion velocity.

H\textsubscript{03}: There is no significant difference between the expected and unexpected groups in peak EMG activity of the peroneus longus.

H\textsubscript{04}: There is no significant difference between the expected and unexpected groups in number of body weights.
$H_{05}$: There is no significant difference between the expected and unexpected groups in time to maximum ankle inversion.

$H_{06}$: There is no significant difference between the expected and unexpected groups in time to peak EMG of the peroneus longus muscle.

$H_{07}$: There is no significant difference between the expected and unexpected groups in time to maximum vertical ground reaction force.

$H_{08}$: There is no significant difference between the expected and unexpected groups in time from peak EMG to maximum ankle inversion.

$H_{09}$: There is no significant difference between the expected and unexpected groups in time from maximum vertical ground reaction force to peak EMG.

$H_{10}$: There is no significant male/female gender difference for any of the dependent variables.

Delimitations

This study was conducted with the following delimitations:

1. Only college aged students from Ohio University participated in the study.
2. Eleven men and 20 women participated in the study.
3. The study only examined the right ankle.
4. Subjects performed single leg drop landings from a height of 20 cm.
5. All subjects were deemed to have healthy ankles through objective and subjective analysis.
6. Ankle inversion and inversion velocity were measured using two-dimensional high speed digital video analysis.
7. Electromyographical data was collected and analyzed for the peroneus longus muscle.

8. Vertical ground reaction forces were measured with a four-channel force plate.

Limitations

The following limitations were observed during this research study.

1. Leg dominance was not taken into consideration.

2. Movement of reflective markers due to skin movement.

3. Exact landing point on the inversion wedge.

4. Different landing styles.

Assumptions

The following assumptions were made regarding this research.

1. Subjects were truthful when reporting the suspected landing surface.

2. All instruments were properly calibrated.

3. Subjects began each trial with his or her foot in the neutral position.

4. Measurements were taken correctly.

5. Subjects were unable to tell when the drop landing platform was moved.

6. Subjects could not see the landing surface.

Definition of Terms

Ankle complex. The talocrural, subtalar, and distal tibiofibular syndesmotic joints as well as the supporting connective tissue (Hertel, 2002).
**Eversion.** Moving the sole of the foot away from the median of the body (Moore & Dalley).

**Inferior.** The structure that is positioned nearest to the sole of the foot (Moore & Dalley, 2006).

**Inversion.** Moving the sole of the foot toward the median of the body (Moore & Dalley, 2006).


**Kinematics.** Study of movements and the forces that are associated with movement (Whiting & Zernicke, 1998).

**Posterior.** The back surface of the body or nearer to the back (Moore & Dalley, 2006).

**Posterioinferior.** A combination of posterior and inferior in reference to anatomical position.
Chapter Two

Review of Literature

The ankle is a very commonly injured joint of the body. Soboroff, Pappius, and Komaroff (1984) reported that more than two million people are affected by ankle injuries every year in the United States. This high incidence of injury to the ankle complex has led to a solid foundation of research. The main focus of this review of literature will be on ankle inversion research; but first it is important to understand some basic anatomy of the ankle complex. Another area that will be discussed is gender differences in drop landings.

Ankle Anatomy

The ankle complex is formed by the talocrural synovial, subtalar synovial, and distal tibiofibular syndesmotic joint. Stability of these joints is achieved through different defense mechanisms. One defense mechanism that gives stability to a joint is the congruency of the joint, which means how well the bones fit together. The primary static defense mechanism includes the joint capsule and ligaments. The muscles that cross the ankle joint act as the primary dynamic stabilizer or dynamic defense mechanism. (Hertel, 2002).

Bony anatomy. The talocrural joint is formed by the superior talus and the distal ends of the tibia and fibula, which are known as the medial and lateral malleoli. The talocrural joint is often seen as a hinge joint because it allows for the motions of plantar flexion and dorsiflexion (Marieb & Mallatt, 2001; Moore & Dalley, 2006). This movement occurs primarily in the sagittal plane. The subtalar joint is formed where the
talus articulates with the calcaneus (Moore & Dalley, 2006). According to Hertel (2002), the subtalar joint is responsible for pronation and supination while Moore and Dalley (2006) state that the subtalar joint performs inversion and eversion. Hertel (2002) describes pronation as a combination of eversion, external rotation, and either plantar flexion or dorsiflexion, while supination is described as a combination of inversion, internal rotation, and either plantar flexion or dorsiflexion. The distal tibiofibular joint is a syndesmotic joint formed by the distal ends of the tibia and fibula, which are held together by the interosseous membrane. This syndesmosis allows very limited gliding movement between the two bones (Hertel, 2002; Moore & Dalley, 2006).

Ligamentous structures. The main static stabilizers of the ankle are the ligaments and joint capsule. The joint capsule is relatively thin both anterior and posterior but is reinforced by the ligaments of the ankle (Moore & Dalley, 2006). The main ligaments of the ankle are the anterior talofibular ligament (ATFL), posterior talofibular ligament (PTFL), calcaneofibular ligament (CFL), and the deltoid ligament.

The ATFL provides support to the lateral ankle and runs from the anteriomedial lateral malleolus to the neck of the talus (Hertel, 2002; Moore & Dalley, 2006; Starkey & Ryan, 2002). The ATFL has been shown to resist anterior displacement of the talus. It also restricts inversion and internal rotation (Hertel, 2002; Starkey & Ryan, 2002).

The PTFL also lies on the lateral side of the ankle and runs from the posterioinferior malleolus to the posterior talus (Hertel, 2002; Moore & Dalley, 2006; Starkey & Ryan, 2002). The PTFL is responsible for protecting against excessive
inversion, internal rotation (Hertel, 2002), and posterior displacement of the talus (Starkey & Ryan, 2002).

The CFL is the third ligament that lies on the lateral side of the ankle. The CFL runs from the posterior inferior tip of the lateral malleolus to the lateral surface of the calcaneus (Hertel, 2002; Moore & Dalley, 2006; Starkey & Ryan, 2002). The CFL is responsible for the restriction of inversion (Starkey & Ryan, 2002), internal rotation, and supination (Hertel, 2002).

The deltoid ligament is a group of four ligaments that lie on the medial aspect of the ankle. These ligaments collectively provide medial support by resisting eversion (Starkey & Ryan, 2002) and subluxation of the ankle joint (Moore & Dalley, 2006).

*Ankle musculature.* While ligaments provide static stabilization the muscles that cross the joint act both concentrically and eccentrically to provide dynamic stabilization of the ankle. The most important muscles with reference to protecting the ankle from injury are the muscles of the lateral and anterior leg (Hertel, 2002). The muscles of the lateral leg include the peroneal or fibularis group. The peroneus longus and peroneus brevis are very important in evertting the ankle. This means that eccentrically these two muscles can slow down or limit excessive inversion of the ankle. The peroneus longus also assists in plantar flexion while the tertius assists in dorsiflexion of the ankle (Marieb & Mallatt, 2001; Moore & Dalley, 2006; Starkey & Ryan, 2002).

Hertel (2002) suggests the anterior muscles may be important in protecting the ankle by eccentrically contracting during forced supination of the ankle. These muscles may slow down the plantar flexion portion of the supination moment (Hertel, 2002). The
muscles of the anterior compartment include the tibialis anterior, extensor digitorum longus, extensor digitorum brevis, and the peroneus tertius (Hertel, 2002; Marieb & Mallatt, 2001; Moore & Dalley, 2006; Starkey & Ryan, 2002). Collectively the main function of these muscles is to concentrically dorsiflex the foot or eccentrically plantar flex the foot.

**Inversion Platform Research**

Tilting platforms are commonly utilized in research to create sudden and dynamic inversion moments. Researchers use these platforms in an attempt to recreate the common mechanisms of injury to the ankle. Many different variables have been examined when using these platforms. The main areas of research include comparing different types of shoes, the effects of taping and bracing, and the reaction of the peroneal muscle group in different situations.

*Shoe differences.* The effects of different shoe types on ankle inversion are well known. Ricard, Schulthies, and Saret (2000) used a tilting platform to compare the rate and amount of inversion in low-top and high-top shoes. Their results indicate high-top shoes reduced the total amount of inversion experienced as well as the maximum and average rate of inversion. A review article by Verhagen, et al. (2001) agreed with Ricard et al. (2000) and found that high-top shoes are more effective at reducing ankle inversion than low-top shoes.

*Adhesive taping.* Much of the research in the area of ankle sprains has focused on prophylactic measures. The main prophylactic measure taken by athletic trainers and athletes alike is the application of adhesive tape and/or bracing. Many studies have
observed that adhesive tape restricts ankle range of motion (Benesch, Putz, Rosenbaum, & Becker, 2000; Johnson & Johnson, 1993; Konradsen, 2002; Konradsen, et al. 2005; Konradsen, Voigt, & Hojsgaard, 1997; Podzielny & Hennig, 1997; Rovere, Clarke, Yates, & Burley, 1988). Prophylactic ankle taping is applied to restrict ankle motion and stimulate mechanoreceptors in an effort to prevent ankle injury. Although ankle taping has been found to reduce ankle motion, it has also been shown to lose its ability to restrict ankle motion after brief periods of exercise (Benesch, et al. 2000; Konradsen, 2002; Konradsen, et al. 1997; Podzielny & Hennig, 1997).

Some studies have examined the effects of different taping styles and the difference between taping and orthotic brace on the amount of ankle motion. There are a variety of different ways to tape an ankle. Frankeny, Jewett, Hanks, and Sebastianelli (1993) compared four different methods of ankle taping. The methods utilized were the basketweave with medial and lateral heel locks, Hinton-Boswell, “basic,” and Gill. The authors found that the Hinton-Boswell method provided the greatest restriction to inversion. The authors also found that all of the taping methods loosened around 50% after brief exercise. Greene and Hillman (1990) assessed the ability of ankle taping and semi-rigid orthosis to restrict ankle inversion and eversion. The authors found both taping and orthosis to be effective in restricting motion. The tape group restricted inversion and eversion by 41% but the restriction was reduced to 15% by the end of a 3 hour volleyball practice. A review of the literature by Callaghan (1997) found that both functional and mechanical stability are improved by tape but the restrictive ability is lost after short bouts of exercise.
Tilting platforms have also been utilized to test the effectiveness of prophylactic taping. Alt, Lohrer, and Gollhofer (1999) used a tilting platform to look at the functional properties of ankle taping. The authors found that taping does improve ankle stability. They found that 35% of the maximal inversion amplitude was decreased during sudden tilt movements. Ricard, Sherwood, Schulthies, and Knight (2000) compared the effects of tape and exercise on ankle inversion before and after exercise with a tilting platform. The authors found that tape increased the time to maximal inversion and reduced inversion velocity. The investigators also found that the tape loosened significantly during exercise. While they did show that tape reduced in effectiveness the authors promote the use of tape because it allows more time for the ankle’s neuromuscular system to react. Verhagen et al. (2001) performed a review on the effect of tape, brace and shoe on ankle range of motion. They similarly noted that ankle taping did significantly reduce ankle inversion and eversion but the effect was reduced after bouts of activity. Lastly, Cordova, et al. (2000) performed a meta-analysis on the influence of ankle support on range of motion. The interventions that were tested included tape, lace up brace, and a semi-rigid brace. Inversion, eversion, plantar flexion, and dorsiflexion were tested before and after exercise. The authors found that taping was best at reducing the motion of dorsiflexion.

**Prophylactic bracing.** Research has found that tape loses its ability to restrict motion after exercise, thus many athletes turn to different types of prophylactic support. These include support such as lace-up bracing and semi-rigid orthosis. Cordova et al. (2002) explored the efficacy of prophylactic ankle support with a literature review. The authors found that ankle tape, lace-up brace, and semi ridged brace all provided
restriction to range of motion. The review reported that the semi-rigid brace was more effective overall and also retained its restrictive capabilities after exercise better than the tape and lace up conditions.

A tilting platform was used to examine the ability of different ankle braces to restrict foot supination (Podzielny & Hennig, 1997). This study found that foot supination, a combination of inversion and plantar flexion, and supination velocity was reduced in three of the ankle brace situations. Ashton-Miller et al. (1996) used a tilting apparatus to examine different prophylactic devices. The authors designed a study to compare the different devices and tested which device the subjects could resist the inversion better with. The study showed that a pre-activated evertor muscle group was better at protecting the ankle than either the taping, bracing or altered shoe height. A comprehensive review article found that tape, non-ridged and semi-ridged prophylactic ankle stabilizers all limit ankle range of motion (Verhagen, et al. 2001). The authors suggest that the semi-ridged prophylactic ankle stabilizers are most effective because they retain their restrictive properties while the other two forms lose restriction after a period of exercise.

Peroneal reaction time. One of the largest areas of research with the ankle is in the peroneal muscle group. This is the muscle group that everts the foot and is the main dynamic protector of ankle inversion. Research of the peroneal muscle group focuses mainly on reaction times but also looks at evertor strength. As previously mentioned, Ashton-Miller et al. (1996) compared evertor muscle strength, shoe height, tape, and three orthoses in an attempt to see which provided the best protection. The authors
reported that the fully activated evertor muscles can provide more than three times better protection than tape or an orthosis worn inside a three-quarter-top shoe. These findings support the research that is being done in the area of the peroneal muscle group.

Konradsen, Olesen, and Hansen (1998) investigated sensorimotor control and eversion strength in acute ankle injury situations. The authors found the athletes’ ankle strength was only 88% of the contralateral ankle 3 weeks post injury. The percentages could be misleading because 9 of the 44 subjects could not complete the strength test after the 3 week period. This strength deficit is another reason research on peroneal reaction times is vital.

Peroneal reaction times have been studied across a variety of different variables. The main areas that have been studied include comparing healthy and injured subjects, healthy and unstable subjects, taping and bracing. Before peroneal reaction times should be an accepted tool in research, the reliability needs to be established. Benesch et al. (2000) established the reliability of peroneal reaction times with a tilting platform. Benesch et al. (2000) reported normative values for peroneal reaction times or latencies and looked at different factors that might affect peroneal reaction time. The authors found the average reaction latency for the peroneus brevis to be 66 milliseconds (ms). The authors observed an average latency of 63 ms for the peroneus longus. With regards to the different factors, the study showed that a warm-up decreased the peroneus brevis latency. Muscle fatigue significantly increased the latency of both the peroneus brevis and longus. Conversely, the authors found that a foot position with 15° of plantar flexion significantly decreased the latency of both muscles.
Most peroneal reaction studies make use of healthy subjects in an effort show how different variables affect peroneal reaction time, while others compare healthy individuals to subjects with unstable ankles. Konradsen et al. (1997) investigated the role of dynamic defense mechanisms of the ankle. Surface EMG measurements of the peroneus longus, peroneus brevis, biceps femoris, and rectus femoris were taken during a sudden inversion of 30°. The peroneal latency was 54 ms with the foot in a neutral foot position, 56 ms with the foot in 10° of eversion, and 51 ms with the foot started in 10° of inversion. The rectus femoris latencies were 68 ms, 69 ms, and 62 ms, respectively, while the biceps femoris had latencies of 73 ms, 69 ms, and 71 ms, respectively. Johnson and Johnson (1993) compared the latencies of both the peroneus longus and brevis in surgical, non-surgical, and healthy subjects. The authors were unable to note any significant differences between the three groups. The average latency of the surgically repaired ankle was 70.8 ms, compared to subjects that were rehabilitated without surgery averaged 65.1 ms. The average latency for the control group of uninjured ankles was 75.2 ms. These numbers may seem to be significantly different at first glance, but the low number of subjects per group and individual group differences caused a lower statistical power.

Another study by Konradsen et al. (2005) examined eversion torque responses to sudden ankle inversion in braced, unbraced, and pre-activated situations. The study utilized surface EMG data of the tibialis anterior and peroneus brevis during a 30° sudden inversion. The average rate motion of the inversion platform during the trials was 200°/s. The average latency of the peroneus brevis muscle to reach 66% of its maximal eversion
torque was 326 ms in unbraced, 230 ms in braced, and only 89 ms for pre-activated subjects. Similarly, Shima, Maeda, and Hirohashi (2005) investigated peroneal latency in subjects with normal and hypermobile ankles. The subjects also randomly had their ankles taped or braced. The authors did not report specific latency times for the peroneus longus. The study reported longer latency for the intact ankles than the other three situations. The study also found the peroneal reflex was delayed in both the taped and braced situations when compared to the control group. Cordova, Cardona, Ingersoll, and Sandrey (2000) looked at the latency of the peroneus longus after wearing an ankle brace for 8 weeks. The thought has been that long term use of ankle braces can cause adverse changes to the ankle and supporting structures (Cordova, Cardona et al., 2000). This study investigated the issue of long term brace use and reported no significant differences between the pre and post tests. The authors concluded that long term ankle brace use neither helped nor hindered the peroneal latency in healthy individuals. Osborne, Chou, Laskowski, Smith, and Kaufman (2001) also performed an 8 week study, but looked at the effect of ankle disk training on peroneal latency. The authors used fine wire EMG in the tibialis anterior, tibialis posterior, peroneus longus, and flexor digitorum longus. Before the 8 week training, the peroneus longus latency for the control group was 53.7 ms and 52.3 ms for the experimental group. After the 8 week training session the latencies were 46.1 and 42.8 respectively. These numbers were not found to be significantly different. The study did find that the tibialis anterior latency reduced significantly.
It is important to investigate injured or unstable ankles due to the high incidence of injury. Vaes et al. (2002) compared peroneal reaction times in healthy and unstable ankles. The authors used a platform with a total inversion of 50°. The authors observed surface EMG of the peroneus longus muscle. The study showed a mean latency of 57.3 ms in healthy subjects versus 58.7 ms for subjects with chronically unstable ankles. This study did not find significantly different latencies but did find something else. The authors reported that sudden inversion was not constant but actually had two distinct deceleration points. These two decelerations relate well to the two peroneal reactions that were found by Nieuwenhuijzen, Gruneberg, and Duysens (2002). Vaes et al (2002) reported the first deceleration point at 28.4 ms and the second deceleration point at 90.9 ms while Nieuwenhuijzen et al. (2002) found the mean first reaction to inversion at 40 ms and the second latency at 100 ms.

Ebig et al. (1997) also performed a study to investigate reaction times of the peroneus longus and tibialis anterior in subjects with chronic ankle instability. Ebig et al. (1997) reported peroneal reaction time in stable subjects to be 65.3 ms and 58.6 ms in unstable ankles. The tibialis anterior reaction time was 71.6 ms in stable versus 67.9 ms in unstable subjects. The latencies for both the peroneal and tibialis anterior muscles were not significantly different between the stable and unstable subjects. Rosenbaum et al. (2000) also investigated reaction times for the peroneus longus and brevis in unstable and stable ankles. Significant differences were reported between the stable and unstable ankles for both muscles. Surface EMG data showed the peroneus brevis reaction times to be 57 ms for the stable group and 65 ms for the functionally unstable ankle. The peroneus
longus had latency times of 54 ms and 60 ms respectively. Both functional instability and mechanical instability were investigated. Reaction times for the functional instability group were significantly longer than the mechanical instability group. Lastly, Konradsen and Ravn (1991) investigated peroneal reaction times in subjects with ankle instability. The authors reported the reaction time or latency for the peroneus brevis to be 69 ms in stable subjects and 84 ms in unstable subjects. The peroneus longus latencies were 65 ms and 82 ms respectively. Konradsen and Ravn’s (1991) results agreed with Rosenbaum et al. (2000), both studies concluded that subjects with functional instability had higher peroneal reaction times.

**Inversion Drop Landings**

Little research has been done combining ankle inversion research and drop landing research. With that said, Nieuwenhuijzen et al. performed a study to introduce a new way to reproduce and investigate rapid ankle inversion. The authors’ methodology investigated ankle inversion during walking and jumping. The study used inversion platforms and methodology that had the subjects inverting their ankle while either walking or jumping. The walking trap door took an average of 67 ms to rotate 25° which was equal to 403°/s. The jumping platform rotated in 42 ms or 595°/s. The study reported that all the muscles being monitored by surface EMG had two typical responses as previously reported. The walking inversion had an average first response at 40 ms and a second response average around 100 ms. The jumping inversion data also showed two responses. The first response occurred at an average of 35 ms, after onset of inversion, while the second response averaged 90 ms. The only muscle to be individually reported
was the peroneus longus. The walking task showed a mean latency of 42 ms for the first response and 93 ms for the second response. The jumping task had a similar first response at 41 ms after onset of inversion while the second response had a latency of 87 ms.

Ubell, Boylan, Ashton-Miller, and Wojtys (2003) also utilized a different way to investigate dynamic inversion. The authors looked at three different braces and their effect on dynamic inversion. This study observed the braces effect when the subjects were actively resisting inversion upon landing from a jump. All three braces showed an increased ability to resist inversion. Ubell et al. (2003) also gave a subjective evaluation to the subjects. The results showed the subjects were more comfortable in the Sweed-O Lok but more confident in the Bledsoe Ultimate and Aircast Sport-Stirrup.

While the previous two studies utilized methods other than inversion platforms, the authors were unable to report ground reaction forces during their jump landings. McCaw and Cerullo (1999) were able to observe ground reaction forces and other kinematic data in their study. The authors did not look at any type of dynamic inversion. McCaw and Cerullo looked at the affect that different ankle stabilizers have on ankle kinematics during drop landings. When data for the control group was compared to the ankle stabilizer group, the stabilizer group showed decreased dorsiflexion and angular velocity.

Gender Differences

Gender comparisons in drop landing research are not very common. Seegmiller and Li (2006) examined the effect gender had on vertical ground reaction forces when
dropping from a height of 30 cm. They found that females landed harder than men, which might put them at a higher risk to injury.

Other studies have shown different results than Seegmiller and Li (2006). Decker, Torry, Wyland, Sterett, and Steadman (2003) did not find any gender differences when landing from a height of 60 cm. Ford, Myer, and Hewett (2003) compared male and female basketball players landing from a height of 31 cm. The authors reported no significant differences in vertical ground reaction force between male and female groups. Quatman, Ford, Myer, and Hewett (2006) performed a longitudinal study to investigate the effect of maturation on landing force and vertical jump. Subjects dropped from 31 cm and then performed a maximal vertical jump. The authors found that over time, males significantly reduced their landing force while females showed no significant change.
Chapter Three

Methods

Design

A multivariate analysis of variance (MANOVA) was used to analyze the data in this study. The independent variables were landing (expected and unexpected) and gender (male or female). The dependent variables included maximum ankle inversion; maximum velocity; peak electromyography (EMG) activity of the peroneus longus; maximum vertical ground reaction force (VGRF); time from toe contact to maximum ankle inversion, peak EMG, and maximum VGRF; time from peak EMG to maximum ankle inversion; and time from maximum VGRF to peak EMG. The maximum VGRF was used to calculate the number of body weights the subject experienced. Data were analyzed with statistical software SPSS, version 13.0, for windows (SPSS Inc, Chicago, IL).

Null Hypothesis

H\textsubscript{01}: There is no significant difference between the expected and unexpected groups in maximum ankle inversion.

H\textsubscript{02}: There is no significant difference between the expected and unexpected groups in maximum ankle inversion velocity.

H\textsubscript{03}: There is no significant difference between the expected and unexpected groups in peak EMG activity of the peroneus longus.

H\textsubscript{04}: There is no significant difference between the expected and unexpected groups in number of body weights.
H_{05}: There is no significant difference between the expected and unexpected groups in time to maximum ankle inversion.

H_{06}: There is no significant difference between the expected and unexpected groups in time to peak EMG of the peroneus longus muscle.

H_{07}: There is no significant difference between the expected and unexpected groups in time to maximum vertical ground reaction force.

H_{08}: There is no significant difference between the expected and unexpected groups in time from peak EMG to maximum ankle inversion.

H_{09}: There is no significant difference between the expected and unexpected groups in time from maximum vertical ground reaction force to peak EMG.

H_{10}: There is no significant male/female gender difference for any of the dependent variables.

Operational Definitions

For this thesis, terms are operationally defined as follows:

Amount of ankle inversion. The difference between the inversion angle at toe contact and the maximum inversion angle within 100 ms of toe contact.

Expected landing. When subjects thought they were going to land on the inversion wedge and did.

Inversion velocity. The rate of ankle inversion during the 100 ms after toe contact.

Maximum vertical ground reaction force (VGRF). The maximum force occurring within 100 ms after toe contact. This point occurred at heel contact for all subjects in this study.
Number of body weights. The amount of force experienced by the body expressed in multiples of its own weight. This figure was obtained using the following calculation \((N/kg)*100\). \(N\) represents the number of Newtons at maximum VGRF and Kg is the subject’s body weight in kilograms.

Peak electromyography (EMG). The highest voltage of peroneus longus activity within 100 ms after toe contact.

Toe contact. The moment when the toe touched the inversion wedge or force plate, as automatically determined by computer software.

Unexpected landing. When subjects thought they were going to land on the flat surface but actually landed on the inversion wedge.

Subjects

Twenty-four subjects with healthy ankles volunteered. There were 11 men and 13 females with a weight \((M = 77.31, SD = 19.34)\) kg, height \((M = 169.70, SD = 10.511)\) cm, and age \((M = 21, SD = 2.15)\) years. A complete demographic breakdown can be found in Table 1. Subjects were excluded from this study if they sustained an injury or undergone surgery to their right ankle during the previous six months. Subjects were also excluded if they experienced unexplained pain, swelling or loss of sensation at the time of data collection. One subject was excluded from the study due to an inability to correctly perform the drop landing. This left 23 total subjects. This study was approved by the Institutional Review Board of Ohio University and prior to participation all subjects read and signed an informed consent form (see Appendix A).
Table 1

Means and Standard Deviations for Age, Height (cm), and Weight (kg) of Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male(^a)</td>
<td>( M )</td>
<td>22.2</td>
<td>177.86</td>
</tr>
<tr>
<td></td>
<td>( SD )</td>
<td>2.0</td>
<td>5.98</td>
</tr>
<tr>
<td>Female(^b)</td>
<td>( M )</td>
<td>19.9</td>
<td>162.21</td>
</tr>
<tr>
<td></td>
<td>( SD )</td>
<td>1.7</td>
<td>8.10</td>
</tr>
<tr>
<td>Overall(^c)</td>
<td>( M )</td>
<td>21.0</td>
<td>169.70</td>
</tr>
<tr>
<td></td>
<td>( SD )</td>
<td>2.2</td>
<td>10.51</td>
</tr>
</tbody>
</table>

Note. cm = centimeters; kg = kilograms

\(^{a}n = 11; \(^{b}n = 12; \(^{c}n = 23.

Instrumentation

Subjects performed a single leg drop landing with their right leg onto a 30° inversion wedge from a height of 20 cm. The inversion wedge was made of steel and had grip tape on it to prevent the subject’s foot from slipping when landing. Figure 1 shows the set up of the platform and inversion wedge. The inversion wedge was placed on a 9281C Kistler force plate that sampled at 1000 Hz (Kistler Instruments Corporation USA). The signal was amplified with an external 8-channel 9865B charge amplifier (Kistler Instruments Corporation USA), and filtered with a fast Fourier filter.
Surface EMG of the peroneus longus muscle was sampled at 1,000 Hz and obtained with the Noraxon Telemyos (Noraxon USA, INC.) telemetry system. The EMG signal was differentially amplified and filtered with a fast Fourier filter. The signal had a common mode rejection greater than 100 dB at 50/60 Hz. The overall gain was set to 2,000. The peroneus longus muscle was located about 1 to 2 cm distal to the fibular head. The area was shaved and cleansed with alcohol. Two solid gel 3M Red Dot Ag/AgCl disc electrodes with an inter-electrode distance of 4.5 cm were placed over the muscle belly. The ground electrode was placed over the patella. Each subject's EMG data were normalized to a ten pound weight prior to each trial (see Figure 2). To normalize, the 10 pound weight was strapped to the ankle of the subject prior to each trial. When instructed, the subject was asked to evert their foot to the neutral position and a manual offset was taken.
Subjects had four 7mm diameter round reflective markers placed on their posterior right ankle and lower leg (see Figure 3). The first marker was placed at the base of the calcaneus. Another marker was placed at the apex of the calcaneus. These spots were designated through palpation by the same researcher for every subject. Then two markers were placed 6 cm and 18 cm above the apex of the calcaneus, along the center line of the lower leg. The markers were centered on the posterior ankle and leg with a standard goniometer. Marker placement and EMG electrode placement were performed by the same researcher for every subject. A Fastcam PCI R2 high speed video camera, sampling at 250 Hz, was used to record each trial. The 2D video data were filtered with a fast Fourier filter. Video, EMG, and VGRF were synchronized with an Event
Synchronization Unit (Peak Performance Technologies Inc. USA) and analyzed with Peak Motus Software, version 8.0 (Peak Performance Technologies Inc. USA).

Figure 3. Reflective marker placement: Subjects lie prone with leg and ankle relaxed. The ankle is placed in neutral position for placement of markers.

**Trial Description**

After signing the informed consent, each subject was assigned a subject number and asked to fill out a medical history form. The subject then had his or her height and weight recorded. Each subject’s ankle was then examined by a Certified Athletic Trainer. After examination and approval for the study, reflective dots were placed on each subject’s right posterior ankle. The reflective markers were placed over the base of the calcaneus, apex of the calcaneus, and then at pre-set distances from the apex of the calcaneus. All the markers were placed in line with each other and down the midline of
the lower leg. The examiner then located the belly of the peroneus longus muscle and prepared the area for surface EMG electrode placement. The surface electrodes were placed in line with the muscle fibers. The examiner then checked the electrode placement to make sure the electrodes were located over the peroneus longus muscle. The electrodes were then secured with pre-wrap and athletic tape.

Each subject was instructed on how to perform the drop landing trials and given time to practice. Subjects were instructed to lift their left leg up as fast as possible and allow the right leg to drop. During the trials, the subject wore dribbling shields to prevent the subject from seeing the floor. The subject wore headphones between trials to drown out the noise of the platform being moved. Each trial occurred as follows. A manual offset of EMG for the peroneus longus was taken. The manual offset was acquired by strapping a 10 pound weight to the subject’s ankle and asking them to evert their foot into the neutral position. While the manual offset was being taken, a research assistant moved the drop landing apparatus to the required position; inversion wedge or flat surface (see Figure 4). The drop landings were randomized between landing onto the inversion platform and landing onto the flat surface. After the manual offset was taken, the subject closed their eyes and was led to the platform by a research assistant. The subject then stood on the 25 cm platform with their left foot and held their right foot off the platform in the neutral position. When told, the subject performed the drop landing as instructed. After the drop landing, the subject was led back to the table to start the procedure over again. The subject performed a maximum of 20 drop landings or until four expected and four unexpected landings onto the inversion wedge were recorded. Since some of the four
expected and four unexpected trials were not usable, the first two usable expected and unexpected trials were averaged for data analysis. After each drop, the subject was asked which surface they thought they were going to land on. This was used to separate the trials from an expected landing onto the inversion wedge and an unexpected landing onto the inversion wedge. An expected landing was when the subject thought they were going to land on the inversion wedge and did. An unexpected landing occurred when the subject thought they were going to land on the flat surface but landed on the inversion wedge. Data was not recorded when the subject landed on the flat force plate. This study only looked at the kinetic and kinematic differences when drop landing onto the inversion wedge.

*Figure 4.* The drop landing platform in the (a) flat position and (b) inversion position. The wedge stays on the force plate while the platform slides.
Chapter Four

Results

The multivariate analysis of variance showed a main effect between the expected and unexpected groups, $F = 10.342, p = 0.000$, $1 - \beta = 1.000$, $\eta^2 = 0.668$. No main effect was observed between male and female groups, $F = 1.631, p = 0.158$, $1-\beta = 0.586$, $\eta^2 = 0.241$. There was no interaction observed between gender and landing, $F = 0.828, p = 0.571$, $1-\beta = 0.304$, $\eta^2 = 0.139$. Means and standard deviations for all variables can be found in Table 2.

Research Question 1

Is there a difference in the amount of ankle inversion between expected and unexpected drop landings?

Analysis. A significant difference was observed between the expected and unexpected landing group for maximum ankle inversion, $F(1,42) = 6.643, p = 0.014$, $1-\beta = 0.712$, $\eta^2 = 0.137$ (see Figure 5). The expected groups mean maximum ankle inversion was ($M = 1.59, SD = 1.47$) °. The unexpected group inverted an average maximum of ($M = 2.94, SD = 2.1$) °.
### Table 2

**Means and Standard Deviations for all Variables.**

<table>
<thead>
<tr>
<th>Group</th>
<th>Male</th>
<th>Female</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td><strong>Maximum Inversion (°)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>1.097</td>
<td>1.19</td>
<td>2.048</td>
</tr>
<tr>
<td>Unexpected</td>
<td>3.235</td>
<td>2.60</td>
<td>2.662</td>
</tr>
<tr>
<td>Overall</td>
<td>2.166</td>
<td>2.25</td>
<td>2.355</td>
</tr>
<tr>
<td><strong>Maximum Velocity (°/s)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>20.547</td>
<td>9.67</td>
<td>27.772</td>
</tr>
<tr>
<td>Unexpected</td>
<td>47.565</td>
<td>37.9</td>
<td>40.872</td>
</tr>
<tr>
<td>Overall</td>
<td>34.056</td>
<td>30.4</td>
<td>34.322</td>
</tr>
<tr>
<td><strong>Peak EMG (V)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>1.680</td>
<td>1.20</td>
<td>2.422</td>
</tr>
<tr>
<td>Unexpected</td>
<td>1.709</td>
<td>0.62</td>
<td>2.239</td>
</tr>
<tr>
<td>Overall</td>
<td>1.695</td>
<td>0.93†</td>
<td>2.330†</td>
</tr>
<tr>
<td><strong>Number of Body Weights</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>2.488</td>
<td>0.39</td>
<td>2.791</td>
</tr>
<tr>
<td>Unexpected</td>
<td>3.040</td>
<td>0.61</td>
<td>2.830</td>
</tr>
<tr>
<td>Overall</td>
<td>2.764</td>
<td>0.57</td>
<td>2.810</td>
</tr>
<tr>
<td><strong>Time from Contact Max Ankle Inversion (s)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>0.061</td>
<td>0.081</td>
<td>0.078</td>
</tr>
<tr>
<td>Unexpected</td>
<td>0.095</td>
<td>0.015</td>
<td>0.076</td>
</tr>
<tr>
<td>Overall</td>
<td>0.078</td>
<td>0.059</td>
<td>0.077</td>
</tr>
<tr>
<td><strong>Time from Contact Peak EMG (s)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>0.044</td>
<td>0.017</td>
<td>0.050</td>
</tr>
<tr>
<td>Unexpected</td>
<td>0.079</td>
<td>0.019</td>
<td>0.082</td>
</tr>
<tr>
<td>Overall</td>
<td>0.062</td>
<td>0.025</td>
<td>0.066</td>
</tr>
<tr>
<td><strong>Time from Contact Max VGRF (s)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>0.075</td>
<td>0.015</td>
<td>0.058</td>
</tr>
<tr>
<td>Unexpected</td>
<td>0.064</td>
<td>0.022</td>
<td>0.062</td>
</tr>
<tr>
<td>Overall</td>
<td>0.070</td>
<td>0.019</td>
<td>0.060</td>
</tr>
<tr>
<td><strong>Time from Peak EMG to Max Ankle (s)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>0.016</td>
<td>0.074</td>
<td>0.028</td>
</tr>
<tr>
<td>Unexpected</td>
<td>0.015</td>
<td>0.019</td>
<td>-0.006</td>
</tr>
<tr>
<td>Overall</td>
<td>0.016</td>
<td>0.050</td>
<td>0.011</td>
</tr>
<tr>
<td><strong>Time from Max VGRF to Peak EMG (s)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>0.031</td>
<td>0.016</td>
<td>-0.008</td>
</tr>
<tr>
<td>Unexpected</td>
<td>0.015</td>
<td>0.016</td>
<td>0.020</td>
</tr>
<tr>
<td>Overall</td>
<td>-0.007</td>
<td>0.028</td>
<td>0.006</td>
</tr>
</tbody>
</table>

*Note.* *p < 0.05* between landing groups, † *p < 0.05* between male and female.
Research Question 2

Is there a difference in inversion velocity between expected and unexpected drop landings?

*Analysis.* A significant difference was observed in maximum inversion velocity between the expected and unexpected landing groups, $F(1,42) = 9.346, p = 0.004, 1-\beta = 0.848, \eta^2 = 0.182$ (see Figure 6). The mean maximum inversion velocity for the expected group was ($M = 27.77, SD = 14.03$) deg/s. The unexpected groups mean maximum inversion velocity was ($M = 44.07, SD = 27.78$) deg/s.
Research Question 3

Is there a difference in peak EMG between expected and unexpected drop landings on an inverted surface?

Analysis. No significant differences were noted between expected and unexpected landings, $F(1,42) = 0.087, p = 0.770, 1-\beta = 0.060, \eta^2 = 0.002$. The expected landing group had a mean peak EMG of ($M = 2.07, SD = 1.02$) V. The unexpected landing group’s mean peak EMG of the peroneus longus muscle was slightly less at, ($M = 1.99, SD = 0.81$) V.

Figure 6. Inversion velocity between of the expected and unexpected landing groups.

* indicates $p < 0.05$ between groups.
Research Question 4

Is there a difference in number of body weights between expected and unexpected drop landings on an inverted surface?

Analysis. A significant difference was observed between the expected and unexpected group for the number of body weights during landing, $F(1, 42) = 4.236, p = 0.046$, $1-\beta = .520$, $\eta^2 = 0.092$ (see Figure 7). The expected group landed with a mean ($M = 2.65$, $SD = 0.49$) body weights. The unexpected group landed significantly harder with a mean of ($M = 2.93$, $SD = 0.50$) body weights.

![Figure 7](image)

Figure 7. Number of body weights at landing between of the expected and unexpected landing groups. * indicates $p < 0.05$ between groups.
Research Question 5

Is there a difference in the amount of time from toe contact to maximum ankle inversion between expected and unexpected drop landings?

Analysis. No significant difference was observed between the expected and unexpected groups for time from contact to maximum ankle inversion, $F(1,42) = 0.799, p = 0.376$, $1-\beta = 0.141$, $\eta^2 = 0.019$. It took the expected group ($M = 0.069$, $SD = 0.072$) s to reach maximum ankle inversion from toe contact. The unexpected group reached maximum ankle inversion in ($M = 0.085$, $SD = 0.047$) s.

Research Question 6

Is there a difference in the amount of time from toe contact to peak EMG between expected and unexpected drop landings on an inverted surface?

Analysis. A significant difference was seen between the expected and unexpected groups in time from toe contact to peak EMG, $F(1, 42) = 55.100, p = 0.000$, $1-\beta = 1.000$, $\eta^2 = 0.567$ (see Figure 8). The expected landing group took less time, ($M = 0.047$, $SD = 0.014$) s, to reach peak EMG than the unexpected landing group. The unexpected group experienced a latency of ($M = 0.081$, $SD = 0.016$) s.
Figure 8. Time from toe contact to peak EMG between of the expected and unexpected landing groups. * indicates $p < 0.05$ between groups.

Research Question 7

Is there a difference in the amount of time from toe contact to maximum vertical ground reaction force between expected and unexpected drop landings on an inverted surface?

Analysis. No significant difference was seen between the unexpected and expected landing groups for time from contact to maximum VGRF, $F(1, 42) = 0.477$, $p = 0.493$, $1-\beta = 0.104$, $\eta^2 = 0.011$. The time to maximum VGRF for the expected group was $(M = 0.066, SD = 0.017)$ s. The unexpected group took $(M = 0.063, SD = 0.018)$ s to reach maximum VGRF from toe contact.
Research Question 8

Is there a difference in the amount of time from peak EMG to maximum ankle inversion between expected and unexpected drop landings?

Analysis. No significant differences were noted between the expected and unexpected groups for time from peak EMG to maximum ankle inversion, $F(1, 42) = 0.920, p = 0.343, 1-\beta = 0.155, \eta^2 = 0.021$. The expected group reached maximum ankle inversion ($M = 0.022, SD = 0.069$) s after peak EMG. The unexpected group took slightly less time, ($M = 0.004, SD = 0.048$) s, to reach maximum ankle inversion from peak EMG.

Research Question 9

Is there a difference in the amount of time from maximum vertical ground reaction force to peak EMG between expected and unexpected drop landings on an inverted surface?

Analysis. A significant difference was also observed between the expected and unexpected landings in time from maximum VGRF to peak EMG, $F(1, 42) = 46.763, p = 0.000, 1-\beta = 1.000, \eta^2 = 0.527$ (see Figure 9). The expected landing group reached peak EMG at ($M = -0.019, SD = 0.022$) s. This means that peak EMG was reached 0.019 seconds before maximum VGRF was reached. The unexpected landing group reached peak EMG ($M = 0.017, SD = 0.016$) s after maximum VGRF was reached.
Figure 9. Time from maximum VGRF to peak EMG between the expected and unexpected landing groups. * indicates $p < 0.05$ between groups.

Research Question 10

Is there a difference in the amount of ankle inversion between male and female drop landings?

Analysis. No significant difference was noted between genders for maximum ankle inversion, $F(1, 42) = 0.125, p = 0.725, 1-\beta = 0.064, \eta^2 = 0.003$. Overall, the maximum ankle inversion for the male group was ($M = 2.17, SD = 2.25$) °. The mean maximum ankle inversion for the female group was ($M = 2.35, SD = 1.59$) °.

Research Question 11

Is there a difference in inversion velocity between male and female drop landings?
Analysis. No significant differences were observed for maximum velocity between males and females, $F(1, 42) = 0.002, p = 0.968, 1-\beta = 0.050, \eta^2 = 0.000$. The overall mean maximum inversion velocity for the male group was ($M = 34.06, SD = 30.36$) deg/s. The mean maximum inversion velocity for the female group was ($M = 34.32, SD = 16.74$) deg/s.

Research Question 12

Is there a difference in peak EMG voltage between male and female drop landings on an inverted surface?

Analysis. A significant difference was observed between male and females in peak EMG, $F(1, 42) = 5.964, p = 0.019, 1-\beta = 0.665, \eta^2 = 0.124$ (see Figure 10). The overall peak EMG of the peroneus longus muscle for males was ($M = 1.69, SD = 0.93$) volts (V). The mean peak EMG of the peroneus longus muscle for the female group was ($M = 2.33, SD = 0.8$) V.
Figure 10. Mean peak EMG of the peroneus longus muscle for the male and female groups. * indicates $p < 0.05$ between groups.

Research Question 13

Is there a difference in number of body weights between male and female drop landings on an inverted surface?

Analysis. No significant difference was noted between genders for number of body weights at landing, $F(1, 42) = 0.102, p = 0.752, 1-\beta = 0.061, \eta^2 = 0.973$. Overall the male group landed with a mean ($M = 2.76, SD = 0.57$) body weights. Overall females landed with a mean of ($M = 2.81, SD = 0.46$) body weights.
Research Question 14

Is there a difference in the amount of time from toe contact to maximum ankle inversion between male and female drop landings?

_analysis_. No significant difference was noted between genders for time from contact to maximum ankle inversion, $F(1, 42) = 0.003, p = 0.957, 1-\beta = 0.050, \eta^2 = 0.000$. Overall, the male group’s mean time from toe contact to maximum ankle inversion was $(M = 0.078, SD = 0.059)$ seconds (s). The female group’s overall mean time from toe contact to maximum ankle inversion was $(M = 0.077, SD = 0.063)$ s.

Research Question 15

Is there a difference in the amount of time from toe contact to peak EMG between male and female drop landings on an inverted surface?

_analysis_. No significant difference was observed between genders for time from toe contact to peak EMG, $F(1, 42) = 0.698, p = 0.408, 1-\beta = 0.129, \eta^2 = 0.016$. Overall, the male group’s time from toe contact to peak EMG of the peroneus longus muscle was $(M = 0.062, SD = 0.025)$ s. The female group’s time from toe contact to peak EMG of the peroneus longus muscle was $(M = 0.066, SD = 0.020)$ s.

Research Question 16

Is there a difference in the amount of time from toe contact to maximum vertical ground reaction force between male and female drop landings on an inverted surface?

_analysis_. No significant difference was noted between genders for time from contact to maximum VGRF, $F(1, 42) = 3.737, p = 0.060, 1-\beta = 0.472, \eta^2 = 0.082$. Overall, the male group took a mean, $(M = 0.070, SD = 0.019)$ s, to reach maximum VGRF from
the point of toe contact. Overall it took females a mean of, \((M = 0.06, SD = 0.015)\) s, to reach maximum VGRF from toe contact.

**Research Question 17**

Is there a difference in the amount of time from peak EMG to maximum ankle inversion between male and female drop landings?

**Analysis.** No significant differences were seen between genders for time from peak EMG to maximum ankle inversion, \(F(1, 42) = 0.070, p = 0.792, 1-\beta = 0.058, \eta^2 = 0.002\). The overall mean time from peak EMG to maximum ankle inversion for the male group was \((M = 0.016, SD = 0.025)\) s. Overall the mean time for the female group to reach maximum ankle inversion after the point of peak EMG was \((M = 0.011, SD = 0.067)\) s.

**Research Question 18**

Is there a difference in the amount of time from maximum vertical ground reaction force to peak EMG between male and female drop landings on an inverted surface?

**Analysis.** A significant difference was noted between genders for time from maximum VGRF to peak EMG, \(F(1, 42) = 6.193, p = 0.017, 1-\beta = 0.681, \eta^2 = 0.129\) (see Figure 11). Overall, the male group’s time from maximum VGRF to peak EMG was \((M = -0.008, SD = 0.028)\) s. Overall, the female group’s time from maximum VGRF to peak EMG was \((M = 0.006, SD = 0.024)\) s.
Figure 11. Time from maximum VGRF to peak EMG between the male and female groups. * indicates $p < 0.05$ between groups.
Chapter Five

Discussion

This sample of college aged students showed significant differences between landing in maximum ankle inversion, maximum velocity, percent body weight, time to peak EMG, and time from max VGRF to peak EMG. The results showed a higher maximum ankle inversion and an increased inversion velocity. The unexpected landing group was also shown to land harder as evident through a larger number of body weights. The unexpected landing group also showed an increased time to peak EMG activity which indicates a longer delay to peak muscle contraction. Results also showed that in the expected landing group, peak EMG occurred before maximum VGRF, whereas peak EMG occurred after the maximum VGRF in the unexpected landing group. One gender difference was an overall increase of peak EMG in females as compared to men. While there was no main effect observed between genders, a significant difference was noted in peak EMG and time from max VGRF to peak EMG between male and female subjects.

Relation of Peak EMG to Maximum VGRF

This thesis was able to relate the peak EMG activity with maximum VGRF. The data showed the peak EMG occurring before maximum VGRF in the expected landing group. Conversely, the unexpected landing group experienced peak EMG activity following maximum VGRF. This could indicate that the expected landing group was pre-activated. The expected group thought the landing surface was going to be inverted so the peroneus muscle fired early to stiffen the joint and protect the ankle. Previous research by Ashton-Miller et al. (1996) showed that the pre-activated evertor muscle group protects
of the ankle complex three times better than taping or orthotic bracing. Similarly, Konradsen et al. (2005) compared peroneal reactions in braced, unbraced, and pre-activated situations. The authors found that the pre-activated group showed the least latency when compared to the braced and unbraced conditions.

**Peroneus Longus Reaction**

Konradsen (2002) compared peroneal reaction times from different research articles and was unable to find consistent results in peroneal reaction time. A number of confounding factors make comparisons difficult. These factors include diverse criteria for defining a peroneal reaction time, the use of various inversion models, and interest in different variables. Some of these variables include healthy vs. unstable, healthy vs. surgically repaired, and changes with bracing. No prior study has compared peroneus longus reaction times in expected and unexpected ankle inversion drop landings.

The reliability of peroneal reaction times and normative data for the reaction of the peroneus longus has been reported (Benesch, et al. 2000). The authors found that the average latency for the peroneus longus in healthy individuals is 63 ms. Other studies have also shown similar peroneus longus latencies. A study by Konradsen et al. (1997) reported the peroneus longus reaction time to be 54 ms. A platform that inverted the foot and ankle 30° from a neutral position was utilized. A comparison of peroneal latency of the ankle between healthy and surgically repaired or rehabilitated ankles has been reported (Johnson & Johnson, 1993). A slightly higher latency of 75.2 ms for the group with healthy ankles was reported. Vaes et al. (2002) reported a reaction time of the peroneus longus of 57.3 ms in healthy subjects. A 50° tilting platform was used and
healthy ankles were compared to unstable ones. The platform had the subject’s foot start in 40° of plantar flexion and 15° on adduction, rather than in the neutral position. A study comparing healthy ankles to those that were classified as chronically unstable has been reported (Ebig, et al. 1997). A latency of 65.3 ms in the healthy stable ankles was observed. In a study by Rosenbaum et al. (2000), subjects were assigned either to a functional instability group or a mechanical stability group. The subject’s good ankle was used as a control in the study. The healthy ankle of the functional instability group had a mean latency of 54 ms. The mechanical instability group’s healthy ankle showed a mean latency of 57.9 ms. The peroneus longus latency data for the expected group in this thesis was similar to those latencies seen in the healthy group of previous research. For this thesis, the mean peroneus longus latency of the expected and unexpected groups put together lies within the range that can be found in the body of literature.

*Ground Reaction Forces*

Ground reaction forces during drop landing ankle inversion have not been reported previously. The inversion model that this study utilized was modeled after a thesis by Schublova (2004). Schublova did not report ground reaction forces; therefore our results were not comparable. Our study was able to successfully separate expected and unexpected landings when subjects landed onto an inverted surface, which has generally been a limitation of previously published research in this area. We found it surprisingly difficult to acquire data for the unexpected landings since subjects usually indicated that they expected the landing surface. However, since ankle injuries generally occur unexpectedly, research models that successfully duplicate the surprise factor of
injury are more valuable than those that do not. Given the significant differences between the unexpected and expected landings, future research should control for this factor.

**Gender Comparisons**

Male and female comparisons with VGRF data have not been thoroughly reported. Seegmiller and Li (2006) examined the effect gender had on vertical ground reaction forces from a height of 30 cm. They found that females landed harder than men, which might put them at a higher risk to injury. Conversely, Decker et al. (2003) did not find any gender differences. The authors compared data when landing from a height of 60 cm. Ford et al. (2003) compared male and female basketball players landing from a height of 31 cm. There were no differences in vertical ground reaction force between male and female groups. Quatman et al. (2006) performed a longitudinal study to investigate the effect of maturation on landing force and vertical jump. Subjects dropped from 31 cm and then performed a maximal vertical jump. Males significantly reduced their landing force while females showed no significant change. This thesis did not find any differences between genders in peak VGRF. However, this may be due to the low drop height. The 20 cm height was selected to reduce the incidence of injury during data collection. However, gender differences may emerge with higher drop heights. We feel that increased drop heights warrant further investigation.

**Conclusion**

There were significant kinetic and kinematic differences between expected and unexpected landing groups during dynamic ankle inversion. Our research model offers an
innovative way of separating these data into expected and unexpected landing groups. This study offers the following conclusions from the data that was analyzed:

1. A significant difference was noted between the expected landing group and the unexpected landing group for amount of inversion. The unexpected landing group showed a significantly greater amount of inversion during the trial than the expected landing group.

2. A significant difference was noted between landings for maximum inversion velocity. The unexpected landing group was observed to have a significantly greater mean inversion velocity than the expected landing group.

3. A significant difference was observed between landing groups in the average number of body weights at maximum VGRF. The unexpected group was shown to have a greater mean maximum VGRF than the expected landing group. This means that the unexpected group landed with more body weights which translates into a harder landing.

4. A significant difference was observed between landing groups for time to peak EMG activity of the peroneus longus muscle. The unexpected landing group had a significantly longer delay to peak EMG than that of the expected landing group. This means that it took longer for the unexpected landing group to reach a peak muscle contraction.

5. A significant difference was noted between landing groups for time from maximum VGRF to peak EMG of the peroneus longus muscle. The unexpected landing group showed a peak EMG after maximum VGRF while the expected landing groups peak EMG occurred before maximum VGRF.
6. There was a significant difference between genders in peak EMG of the peroneus longus muscle. The female group showed an average peak EMG that was significantly higher than the male group.

7. There was a significant difference between genders for time from maximum VGRF to peak EMG. The females were shown to reach peak EMG after maximum VGRF was reached. The males reached peak EMG before they obtained maximum VGRF.

This thesis demonstrates several significant differences between expected and unexpected single leg drop landings onto an inverted surface. Overall, the data for the unexpected group was suggestive of a higher chance for injury. First, the unexpected landing experienced a greater amount of inversion and faster rate of inversion. Secondly, the unexpected group took longer to reach peak EMG of the peroneus longus muscle and landed with more force, which puts more force on the ankle and body. Lastly, the unexpected group reached peak EMG after maximum VGRF while the expected group reached peak EMG before maximum VGRF. For the unexpected group, this means that the maximum force was transmitted to the ankle before the muscle could react and protect the ankle. This puts the individual at a higher risk for injury. The expected groups muscle reacted before the body received the highest force during the drop landing, therefore enabling better protection of the ankle. With the delayed muscle reaction and increased forces during landing the unexpected group is clearly at a higher risk of injury, when compared to the expected group. Since the expected and unexpected groups are
significantly different, future researchers focusing on drop landing ankle inversion should separate trials into expected and unexpected landings.

Recommendations

Future research should investigate the limitations of this research and expand on the current research in the literature. It would be beneficial to compare the kinetics and kinematics of unexpected landings between the inverted surface and flat surface. It might also be valuable to compare unexpected landings between subjects that have healthy ankles and those that have some type of instability. It would be important to pre and post test unstable ankles with a rehabilitation protocol to see if there are any changes. It might be important to examine different ways to separate between expected and unexpected surfaces. Examining the effect that leg dominance has with expected and unexpected landings may also prove to be valuable. Lastly, future research with this design should compare landings from different heights onto the inverted surface in order to ascertain if there are any gender differences in VGRF between males and females.
References


Appendix A

INFORMED CONSENT FORM
Title of Research: Kinetic and Kinematic Differences in Expected and Unexpected Drop Landing Ankle Inversion

Principal Investigator: Jeremy Dicus, ATC
Co-Investigator: __________________
Department: RSPS

Federal and university regulations require signed consent for participation in research involving human subjects. After reading the statements below, please indicate your consent by signing this form.

Explanation of Study

Purpose of the research
The purpose of this project is to compare kinematic (movement) and kinetic (forces) differences during drop landing ankle inversions (turning the ankle inward). Two types of inversion may occur: stable and unstable. Stable drop landing ankle inversion occurs when the data from the drop landings shows the subject knew they were landing on the inversion wedge. An unstable drop landing ankle inversion occurs when the subject did not know they were landing on the inversion wedge.

Procedures to be followed
I understand before anything else that participation in this study is completely voluntary. I will read and sign the informed consent form before any data collection can begin. After signing the informed consent form I will be assigned a subject number and fill out the functional stability questionnaire. I will then have my right and left ankles examined by the primary investigator who is a Certified Athletic Trainer. I will be cleared to participate in the study after I have signed the informed consent form, completed the functional stability questionnaire and passed the ankle exam given by the primary investigator. The primary investigator will then clear me for the study, which means I can participate in the study if I still want to. After I am cleared I will have reflective dots placed on my right ankle. I will have surface EMG electrodes placed over a muscle in my lower right leg. I understand that I will have a small portion of my lower right leg shaved so the electrode can be placed directly to my skin. The examiner will check to make sure the electrode is placed over the correct muscle. After this is done the electrodes are secured with pre-wrap and athletic tape.

I will then be instructed on how to perform the drop landing trials. I will be given time to practice. During the trials I will wear dribbling shields that do not allow me to see the floor. I will also have head phones on to drown out surrounding noise. The head phones will be set at a level of 100 dBSPL which, according to OSHA regulations, is safe for up to 2 hours of continual noise. Each trial will occur as follows. A manual off set of EMG for the lower leg muscle will be taken. While this is being done, a research assistant will randomly change the landing surface between the inversion wedge and the flat
surface. The drop landing trials will be randomized between landing onto the 30 degree inversion platform and landing onto the flat force plate. I will not know which surface I am going to land on but I will have practiced landing on both surfaces already. The research assistant will then lead me to the platform. I will not try to look and see what surface I am going to land on. When I am told I will perform a drop landing the way I was taught and the way I practiced. After the drop landing, I will repeat the same procedure over again. I will perform a maximum of twenty drop landings. I will not know whether I am landing on the 30 degree inversion wedge or onto the flat surface.

**Duration of subject’s participation**
I will only be required to attend one data recording session. This session is scheduled to last 90 minutes but I understand that the session may take longer than 90 minutes. I understand that all aspects of the study will occur during this session. This will include any questions I have about this form, filling out a functional stability questionnaire, having my right and left ankles examined, instruction and practice of the trials and the completion of the twenty experimental trials.

**Identification of specific procedures that are experimental**

N/A

**Risks and Discomforts**
I understand that there is a possibility that I could sustain an injury by losing my balance and falling during the drop landing. To prevent this from happening there will be a padded handle bar in place. I will be instructed that if at any point they feel like I might lose my balance or get hurt I should grasp the padded handle bar. The padded handle bar will allow me to regain balance and take weight off of the ankle during the inversion drop landing. The other risk is that there is a possibility that I could sustain an inversion sprain to their ankle. The research design utilized in this study will mimic the design that is commonly used in ankle inversion research. Using a 30 degree inversion moment is common in ankle inversion research. With 30 degrees being the norm, there was a study that performed sudden inversion of 50 degrees. This investigator has not come across an ankle inversion research study that has reported an injury during testing or data collection. With that said, there are many steps being taken to prevent any injury to the ankle complex. First off, there is the padded handle bar that has already been mentioned. Secondly, there is foam padding next to the inversion wedge. This foam padding will prevent my ankle from inverting beyond its limits and add support to the leg as the subject lands. There will also be a spotter to assist me to the inversion platform. The spotter will be located behind me during the trials to catch me if I lose my balance. The spotter will also have the responsibility of making sure the area is safe. The spotter will move all equipment and other items away from the testing area to ensure my safety. Lastly, the investigator will take a history and perform an examination to rule me out of the study if my ankle is at a higher chance of injury. In the event that an injury does occur or that I do have pain I will inform the primary investigator immediately.
Benefits

I understand that there are no real direct benefits to me. I understand that my data will be made available to only me upon request. I understand that the specific aims of this research study are to identify the muscle activity, forces and ankle inversion (turning the ankle inward) between stable and unstable inversion drop landings. I understand that the end goal of this research project is to gain a better understanding of the forces and movements that occur during inversion drop landings. Ankle inversion injuries are very common in athletics. The information gained from this research study will add to the base of knowledge that already exists on ankle inversions. The information will be new because this is some of the first research on ankle inversion drop landings. Most research that is done on ankle inversion utilizes platforms with trap doors not drop landings.

Alternative Treatments (if applicable)

N/A

Confidentiality and Records

My confidentiality will be protected at all times through subject number coding. I will be identified on video only by subject number and trial number. Also, the video recording will only record the lower portion of my leg so identification is impossible. I understand that all subject information will be kept in a locked filing cabinet in the office of Dr. Seegmiller, Grover Center E186. Only the primary investigator and research mentor will have access to this information. At the completion of the study all subject information will be shredded and all digital video recordings will be deleted.

Compensation

I understand that no compensation will be offered to me for participating in this study.

Contact Information

If you have any questions regarding this study, please contact (Jeremy Dicus, (740) 821-2775, jd245105@ohio.edu or Jeff Seegmiller, (740) 593-9497, seegmill@ohio.edu).

If you have any questions regarding your rights as a research participant, please contact Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

I certify that I have read and understand this consent form and agree to participate as a subject in the research described. I agree that known risks to me have been explained to
my satisfaction and I understand that no compensation is available from Ohio University and its employees for any injury resulting from my participation in this research. I certify that I am 18 years of age or older. My participation in this research is given voluntarily. I understand that I may discontinue participation at any time without penalty or loss of any benefits to which I may otherwise be entitled. I certify that I have been given a copy of this consent form to take with me.

Signature_________________________ Date______________

Printed Name____________________
Appendix B

FUNCTIONAL AND CLINICAL STABILITY QUESTIONNAIRE
Functional Stability Questionnaire

Subject Number:_______

Have you ever had surgery on your ankle? Y N
Have you ever broken either of your ankles? Y N
Has your ankle ever been immobilized or braced? Y N
Have you hurt your right ankle in the last six months? Y N

If you answered yes to any of the above questions please explain:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Clinical Stability Examination

Observation: If yes explain:

Swelling Y N ________________________
Deformity Y N ________________________
Pain Y N ________________________

Anterior Drawer Test:

Left + -
Right + -

Talar Tilt Test:

Left + -
Right + -

Range of Motion:

Left: Inversion_______ Eversion_______ Plantarflexion_______ Dorsiflexion_______
Right: Inversion_______ Eversion_______ Plantarflexion_______ Dorsiflexion_______

Cleared to Participate: Y N

____________________________________________________
Signature of ATC Date
Appendix C

DATA COLLECTION SHEET
Data Collection Sheet

Date:___________

Informed Consent:  Y  N

Subject Number:__________

Sex:  M  F

Age:_______

Height:___________      Weight:_________

Comments:

S___T___:  _______     Neutral     Positive     Negative     _________________________
T___:  _______     Neutral     Positive     Negative     _________________________
T___:  _______     Neutral     Positive     Negative     _________________________
T___:  _______     Neutral     Positive     Negative     _________________________
T___:  _______     Neutral     Positive     Negative     _________________________
T___:  _______     Neutral     Positive     Negative     _________________________
T___:  _______     Neutral     Positive     Negative     _________________________
T___:  _______     Neutral     Positive     Negative     _________________________
T___:  _______     Neutral     Positive     Negative     _________________________
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T___:  _______     Neutral     Positive     Negative     _________________________
T___:  _______     Neutral     Positive     Negative     _________________________
T___:  _______     Neutral     Positive     Negative     _________________________
T___:  _______     Neutral     Positive     Negative     _________________________

CALIBRATION VIDEO CLIP:  Yes____       No____