MEASUREMENT OF BALANCE DISRUPTION FOLLOWING A LOWER EXTREMITY INJURY IN FEMALE SOCCER PLAYERS

by

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ABSTRACT

Measurement of Balance Disruption Following a Lower Extremity Injury in Female Soccer Players

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Computerized Dynamic Posturography has recently provided a means of objectively measuring balance and postural stability. Using this technology to compare pre-injured data with post-injury data can aid athletic trainers in monitoring the assessment of balance while determining when to return an athlete to participation. The purpose of this research is to determine if balance measurements are influenced by injury and the rate at which balance is restored as the athlete is returned to play. A qualitative design was conducted using a case study format. Seven female Division I soccer athletes served as subjects. All subjects experienced lower extremity injuries during the competitive season and were returned to play during that same season. Subjects’ balance, postural sway, and stability were measured in spring using the Neurocom® Smart Balance Master. These measurements included Sensory Organization Test, Motor Control Test (MCT), and Adaptation Test (ADT). Once injured the subjects were measured: (1) as soon as they were able to bear weight on the affected leg; (2) once they
were cleared to return to play; and (3) 2 weeks after they had returned to play. The measurements were compared to the baseline testing and also to each other in order to determine changes in balance throughout the rehabilitation and return to play process. Compared to the athlete’s baseline data, post-injury data showed weight symmetry changes (unloading involved limb), increased latency scores during the ADT, and ankle/hip dominance shifting toward hip preference. As the rehabilitation process continued, most of the variables that had been disrupted migrated toward a return to pre-injury baseline. Two weeks after the subjects had been cleared to return to participation the majority of balance variables were either equal to or greater than baseline. Athletic trainers need to consider many factors when determining when an athlete should be cleared to participate following an injury. Balance and postural stability are important factors in decreasing re-injury as well as improving overall performance. Utilizing new technologies that provide more objective information on balance gives the clinicians more information to help them make return-to-play decisions. (93 pages)
PUBLIC ABSTRACT

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The main purpose for this study is to determine how balance is disrupted following an injury using the Neurocom Balance System, and also to track the progression through the rehabilitation process until the athlete is returned to participation. There are many reasons that this is beneficial not only to athletic trainers but also to the athletes. This provides objective information on the status of a person’s balance, which prior to new technologies like the Neurocom System was impossible to measure. Athletic trainers can utilize this information to make better educated decisions regarding the athlete’s rehabilitation, treatment, and return to participation. They can also help athletes in objectively knowing how they are progressing throughout the rehabilitation process and can assist in goal-setting, which is an important factor during rehabilitation.
ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

Division I collegiate athletes are some of the most elite athletes in the United States outside of the professional leagues and tours. These athletes are playing at a very high level and their performance could determine if their athletic career continues on to the professional level. Because of the intensity and importance of the game at this level many athletes experience injuries throughout their four years of eligibility. The NCAA Injury Surveillance System has tracked injuries from women’s soccer since the 1988 competitive season, during both practice and games (Dick, Putukian, Agel, Evans, & Marshall, 2007). Their data has shown that the injury rate for women’s soccer is at 16.44 per 1000 exposures for games and 5.26 per 1000 exposures for each practice. The large differences in those results are due to the increase in intensity during games. The Surveillance System also showed that during pre-season practices injury prevalence rose to 9.52 per 1000 exposures compared to 2.91 per 1000 exposures for in-season practices. Approximately 70% of all injuries sustained during that time span were to the lower extremity, which will be the main focus of this study. The clinicians that are working with these athletes need to be aware of how to return an athlete to competition only once they are healthy and it is safe to do so. This return to play decision can often become a very difficult one to make for the athletic trainers, team physicians or other medical personnel involved. The decision is based on all of the information acquired about the athlete and their injury throughout the entire treatment and rehabilitation process. It is helpful for the clinicians to have objective measures that can assist them in making these return to play decisions. Muscle strength, joint range of motion, and amount of swelling
are among some of the objective measures a clinician can use to aid them in this
decision. One important aspect to return to play following an injury is balance and
proprioception. Many of the tests for balance are subjective and rely on the assumption
that their balance was the same in both extremities prior to the injury. There have been
several new products that have recently been introduced to clinicians that aid in obtaining
an objective measure of balance. Many of the new pieces of equipment that are available
to clinicians will be discussed later in this review. In this study the Neurocom Smart
Balance Master will be used in determining if there is a deficit in balance and
proprioception and how much should be regained before allowing the athlete to
participate following a lower extremity injury.

Balance plays an important role for an athlete and subsequently it is important for
the athletic trainer and other members of the sports medicine team to be informed on how
balance decreases the rate of injury, increases performance, and is an important aspect in
the return to play decision. It is important for clinicians to make the connection between
research and practical applications, specifically for return to play decisions following an
injury. “Balance is a complex process involving coordination of multiple sensory, motor,
and biomechanical components” (Nashner, 1993). Balance is composed of feedback
from three sensory sources. The vestibular, visual and proprioceptive areas all relay
information to the muscles in order to generate the appropriate muscular contractions to
maintain balance (Guskiewicz & Perrin, 1996). Balance is an important aspect
specifically for sports because it is needed to perform most sports movements, and as a
method used to decrease risk of injury. Clinicians working with athletes need to be
educated on the importance of balance and a way to objectively measure balance in order
to make a more informed return to play decision. An athlete that has a balance deficiency is more vulnerable for re-injury of an old injury or predisposing them to a new injury due to the decrease in balance and specifically proprioception (Hrysomallis, 2007).

**Purpose of the Study**

As a Sports Medicine clinician, one of the responsibilities is determining when an athlete is ready to return to play following an injury. There are many aspects that go into making a return to play decision including, amount of tissue damage that occurred, amount of swelling, range of motion, muscle strength, if the athlete is able to protect the injured area, risk of re-injury, proprioception, etc. Balance and postural stability is an important aspect that has yet to have a quality method of being objectively measured that can be used by clinicians to aid in making the return to play decision. Many new methods of measuring balance and postural stability have become available and are beginning to be implemented into sports medicine facilities. It is important for clinicians to be aware of the new equipment that is available and how to use them as an aid for return to play decisions. The problem that this study will be focusing on is determining how much balance is disrupted following a lower extremity injury and does it improve through the rehabilitation process as the athlete is returned to participation and afterwards?
Hypothesis

Balance has been studied in depth about its ability to decrease the risk of an injury when it is developed properly. Using that same information it seems appropriate that in order to return an athlete back to competition following an injury that clinicians first need to decrease the risk of re-injury as much as possible; to accomplish this balance and postural stability needs to be regained to an appropriate level. Therefore for this study it is hypothesized that lower extremity injuries result in a significant decrease in balance parameters. A secondary hypothesis is that as the athlete is progressed through a rehabilitation program and back to full participation the balance parameters that were disrupted will trend back towards baseline levels.

Significance of the Study

Athletic trainers and other health care professionals involved in athletics need to be aware of the new technology that is available and the capabilities they possess. The research that has been done using the Neurocom Balance system is quite limited because it is fairly new to the sports medicine market. Most of the current research done using this machine has been focused on concussion assessments, postural stability disorders and vestibular dysfunction. This equipment has many capabilities that have yet to be researched; this study is looking to add to the current research to help broaden the use of the Neurocom Balance system. If an institution has access to this equipment, then it should take advantage of that and utilize it on an everyday basis. That is what this study
is trying to accomplish, is an everyday use for this technology that is helpful to the clinicians that have access to it.

Athletic trainers are involved in the prevention, evaluation, and treatment of lower extremity injuries on a daily basis, so it is important to have an objective method of evaluating balance and postural stability. Specifically as the athlete is involved in a rehabilitation program, it provides the athletic trainer with objective information about the status of the athlete, as well as provides a means of setting goals for the athlete throughout the rehabilitation process regarding balance and postural stability.
CHAPTER II

REVIEW OF LITERATURE

The purpose of this literature review is to provide an overview of the current balance assessment tests and tools that are typically used by athletic trainers; this will include both subjective tests and objective tests. This review will also discuss the different components of balance and give a background of how balance and stability is disrupted when an athlete is injured. It will also provide information on factors that contribute to injury prevalence in the lower extremity and show how many can contribute to one injury. Finally research on the Neurocom Balance System will be reviewed in order to provide the reader with a background of the equipment that will be utilized as well as an understanding of some of the research that has been conducted using this technology.

**Injury Prevalence in Soccer**

Soccer is an intermittent sport that requires many different speeds by the players, such as walking, jogging, running and sprinting (Wong & Hong, 2005). It also requires significant changes of direction, quick changes of speed, contact with other players and also very high fitness level. Women’s soccer has been shown to have higher game injury rates at 16.44 per 1000 exposures than softball (4.3), women’s volleyball (4.6), baseball (5.8), women’s lacrosse (7.2), women’s basketball (7.7), women’s field hockey (7.9), men’s basketball (9.9), men’s lacrosse (12.6), women’s ice hockey (12.6), women’s gymnastics (15.2), and men’s ice hockey (16.3) (Hootman, Dick, & Agel, 2007). Women’s soccer has also been shown to have higher practice injury rates at 5.26 per
1000 exposures than baseball (1.9), men’s ice hockey (2.0), women’s ice hockey (2.5),
softball (2.7), men’s lacrosse (3.2), women’s lacrosse (3.3), women’s field hockey (3.7),
women’s basketball (4.0), women’s volleyball (4.1), men’s basketball (4.3), and men’s
soccer (4.3). Non-contact injuries generally are more frequent in soccer than contact
injuries, with the main mechanisms being running, twisting or turning, kicking and
landing (Wong & Hong, 2005).

There are many definitions of an injury, a few include “any condition that caused
a player to be removed from a game, miss a game, or to be disabled enough to come to
the medical tent” (Kibler, 1993), another definition is “one received during training or
competition which prevented the injured player from participating in normal training or
competition for more than 48 hours, not including the day of the injury” (Hawkins,
Hulse, Wilkinson, Hodson, & Gibson, 2001). Some researchers only define an injury by
missing a game or match, because especially with professional clubs and teams many
players will miss a practice simply to rest not necessarily because they are injured. Other
definitions include missing games or practices, while others do not use time as a factor.
One definition that is simple and focuses on the tissue damage is “act that damages or
hurts” (Arnheim & Prentice, 2000). For this study an injury will be defined as “any
physical complaint sustained by a player that results from a football (soccer) match or
football training, irrespective of the need for medical attention or time loss from football
activities” (Fuller et al., 2006).
Pathology of an Injury

Lower extremity injuries can occur to many different structures including but not limited to skin, fascia, muscles, tendons, ligaments, nerves, blood vessels, joints, and bones. All injuries exhibit different characteristics, as well as different signs and symptoms; however a process common to all injuries is inflammation (Starkey & Johnson, 2006). Inflammation is defined as a localized tissue response initiated by injury to or destruction of vascularized tissue that are exposed to excessive mechanical load or antagonistic agents (Starkey & Johnson, 2006). This process is initiated by tissue cell death or necrosis and has to occur in order to lead to tissue repair, regeneration or scar formation.

When an injury is obtained by an athlete there are many disruptions to that area of the body which may or may not require time off from their sport. There are many different types of tissue that can be damaged, including bones, fascia (connective tissue), cartilage, ligaments, nerves, blood vessels, tendons, muscles and skin (Arnheim & Prentice, 2000). Healing time will vary based on the type of tissue, body part, the location, the person’s healing rate, etc. Although for some injuries there are pretty appropriate time lines for healing, many injuries the healing time will vary based on the individual case.

Every injury that occurs produces a response called inflammation; it is the mechanism the body uses to heal injured tissue. Inflammation has three main functions; first it provides the injured structure with an exudate that contains proteins and immune cells to boost the local defense mechanism and destroys infective agents, like bacteria and
viruses. Second it removes the necrotic debris from the area and third it repairs, regenerates, revitalizes and strengthens the affected tissue (Starkey & Johnson, 2006). This response must occur for the successful repair of injured tissue.

The inflammation process occurs at the cellular level, but other aspects are affected in an overall whole body review. Not all injuries suffer from the same signs and symptoms but with a majority of acute injuries an athlete will experience some or all of the following signs and symptoms: swelling, pain, decreased range of motion, decreased strength, decrease in proprioception, loss of function, decreased agility, biomechanical adaptations, muscular imbalances (Deleget, 2010; Russell, 2010; Silder, Thelen, & Heiderscheit, 2010). This study will mainly be focusing on the loss of balance and postural stability following an injury and using new technology to better aid in measuring that deficit.

Beyond the cellular damage that occurs during an injury other facets are affected by the tissue damage that has occurred including range of motion, joint laxity, muscular strength, muscular flexibility, and proprioception. The main focus of this study is on proprioception and the other aspects of balance. The somatosensory receptors that are found in tissue are damaged when an injury occurs; therefore proprioception is affected by the injury (Hrysomallis, 2007). This provides a decrease in overall balance and postural stability, which is an important aspect in determining when to return an athlete to competition following an injury. The other factors that are decreased following an injury are easily measured using objective measures, so it provides quality information about when to return athletes after an injury. Measuring proprioception following an injury is typically performed by a subjective test, which is compared to the uninjured leg
(Guskiewicz & Perrin, 1996). Many methods of how to measure proprioception will be looked at further later on in this review. Using an objective measurement of balance that compares post-injury balance to pre-injury balance on the same extremity is the most effective way to determine if balance and postural stability has been fully returned before clearing an athlete to return to competition.

**Factors Contributing to Injury**

An injury is sustained by an athlete due to a very wide variety of intrinsic and extrinsic factors. Most injuries are likely due to a combination of factors. Some of the extrinsic factors that can contribute to an injury include level of competition, skill level, shoe type, bracing/taping, or playing surface (Murphy, Connolly, & Beynnon, 2003). Other factors that play a role in an athlete getting injured are intrinsic factors such as age, gender, phase of menstrual cycle, previous injury, inadequate rehabilitation of previous injuries, aerobic fitness, fatigue, body size, limb dominance, flexibility, joint laxity, muscle strength, muscle imbalances, reaction time, limb girth, postural stability, anatomic alignment, gait and foot morphology (Murphy et al., 2003). Some of these factors can be corrected while others are unable to be manipulated. Athletic trainers and other health care professionals need to be aware of the different factors that may result in an injury so that they can properly address the issues that need corrected.
Components of Balance

Balance can be defined as “a complex process involving coordination of multiple sensory, motor, and biomechanical components” (Nashner, 1993). A person has the ability to sense the position of their body and extremities in relation to their surroundings and the gravitational pull on them (Nashner, 1993). Balance is achieved by whole body activation; it requires motions at all of the joints in the lower extremity and by the body’s core musculature (Guskiewicz & Perrin, 1996). Balance is achieved by a combination of somatosensory (proprioception), visual and vestibular feedback that is relayed to the brain. The brain then sends signals to certain muscles to contract or relax in order to maintain an upright position (Gaerlan, 2010).

Overview of Proprioception

Proprioception is the feedback mechanism from sensors within the muscles and tendons, specifically the muscle spindles and the Golgi tendon organs (GTO). The muscle spindles provide information to the brain that refers to the muscle length or the rate of muscle length (Guskiewicz & Perrin, 1996). The information is either sent to the spine and relayed to the brain or it is sent to the spine and connects to a “reflex arc” that sends the information back to the muscle in order to complete the “stretch reflex” (Guskiewicz & Perrin, 1996). The stretch reflex is a defense mechanism that causes the muscle to contract as a protection against being overstretched and injured (Gaerlan, 2010). The Golgi tendon organs are receptors that are located in the tendons of the muscle, and their main function is to relay information about muscle tension or the rate of
change in muscle tension (Guskiewicz & Perrin, 1996). The GTOs are also a defense mechanism that is responsible for relaxing a muscle that is overstretched so it is less likely to get injured. The muscle spindles are the mechanism that acts quickly and first, and then the GTOs begin to relax the muscle after a few seconds, so the two are not competing against each other (Gaerlan, 2010). As the GTOs sense that the muscle tension is past its normal motion or limits it inhibits the motor neurons of the contracting muscle to protect against tissue damage (Guskiewicz & Perrin, 1996).

**Overview of the Visual Component of Balance**

The visual system also provides feedback to the brain about the body’s position in space. Saccades use quick, jerking eye movements in order to track fast moving targets, while smooth pursuits of the saccades are used to track slow moving targets (Irrgang, Whitney, & Cox, 1994). Peripheral vision also plays a very important role in the visual aspect of balance; it relays information about the environment and the body’s position in space (Irrgang et al., 1994). Visual acuity does not seem to affect the ability to maintain postural stability (Irrgang et al., 1994).

**Overview of the Vestibular System**

The vestibular system is also responsible for maintaining balance, by means of the boney labyrinth that is located in the temporal bone (Guskiewicz & Perrin, 1996). The vestibular system is used mainly for slow body sway and it aids in determining linear and angular acceleration (Irrgang et al., 1994). Very few postural reflexes rely solely on the
vestibular system for postural control, because the vestibular system works in conjunction with the visual system as a means of maintaining balance (Guskiewicz & Perrin, 1996).

The vestibulo-ocular input takes information from the vestibular system to aid in controlling the ocular muscles in order to determine one’s position in space (Irrgang et al., 1994). The vestibulo-ocular system is used to keep the eyes on a focal point when the head position is moving (Guskiewicz & Perrin, 1996). The vestibular system senses the head movement and relays that information to the ocular muscles so that they move in the opposite direction of the head movement in order to maintain focus on one spot (Irrgang et al., 1994). This is how a ballerina can maintain an upright position and avoid dizziness by keeping their gaze on one spot while they spin multiple times; they have trained their vestibulo-ocular system to keep them balanced.

**Current Methods Used to Measure Balance**

There are many methods of measuring balance available to clinicians, there has not yet been put into effect a universal way of determining an athlete’s proprioception or balance. Many methods have been designed because they can be performed “on the field” and require no equipment; these tests are mainly for the athletic trainers and physicians trying to make a return to play decision in the middle of a game or match and are on the sidelines with little equipment available at that time. These tests are of a subjective nature and do not compare an athlete’s baseline proprioception status with the current status. There are also tests that are objective and measure balance using extremely sophisticated technology. It is imperative that whatever method used needs to
be performed pre-injury (baseline testing) and then again post-injury in order to better assess the patients balance status.

Subjective Tests for Balance

The Romberg test is one of the simplest tests for assessing static balance (Garcin, 1969). The subject stands with their feet together, arms at their side and eyes close, the clinician determines if there is a fall or postural sway to one side, which would indicate a loss of proprioception. This test can also be performed in the tandem stance heel to toe. The Romberg test is often discredited because it has a lack of sensitivity and objectivity (Guskiewicz & Perrin, 1996).

The single leg balance test is one of the most convenient ways to measure balance that is slightly more useful than the Romberg Test. It is used in many high schools and smaller colleges or universities because it requires very little equipment. It is performed by simply having the athlete take off their shoes and socks, stand on one foot without their legs touching, and staring at a spot on the wall (Trojian & McKeag, 2006). Once the athlete has gained a balanced position they close their eyes and must maintain that position for 10 seconds (Trojian & McKeag, 2006). The test is scored based on a pass/fail grading (Trojian & McKeag, 2006). The scoring is based on the feedback from the athlete, if they report feeling any sense of imbalance during the test it is a positive test (Trojian & McKeag, 2006). The clinician who is running the test then reports if the athlete’s non-weight bearing leg touched the weight bearing leg, the feet moved on the floor, the non-weight bearing foot touches down, or the arms move from their start position (Trojian & McKeag, 2006). The athlete can attempt two trials, if they fail the
first trial, and the test is performed on both legs (Trojan & McKeag, 2006). The use of a foam mat or a tilt board can also be used during this test with eyes open or eyes closed to increase the degree of difficulty (Emery, 2003). This test provides very little information about the athlete’s balance status, it is subjective based on what the athlete reports and what the clinician interprets as a pass or fail rating. It fails to provide a number of miscues or errors and therefore a person with one small movement gets the same positive test as someone who cannot obtain single leg balance at all. Static balance assessments are also criticized because they may not be sensitive enough to determine deficits relating to sports performance or the dynamic balance demands that are required for most sports. It is a very quick and inexpensive test to perform and therefore would have some benefits to clinicians who have very few resources.

The Star Exertion Balance Tests (SEBTs) is a dynamic stability testing and it may be more accurate for lower extremity balance in athletes than a static balance test (Olmsted, Garcia, Hertel, & Shultz, 2002). The test is performed with the athlete standing on one leg in the middle of the testing area which has 8 lines extending outward from the center each at a $45^0$ angle, as seen in the picture above. To perform the test the athlete stands on one leg and reaches the opposite leg out in the direction of one of the lines placed on the floor and gently touches the toe down on the line once they have reached their maximum distance, then return the leg to the center. The examiner then measures from the center of the star to where the athlete touched on the line; the test is then repeated for each direction and on both legs. Prior to the test the athlete is given an opportunity to practice each direction and each foot so they are sure to perform it properly and it is suggested that they warm-up for a few minutes so they have optimal
flexibility and muscle activation before the test begins (Olmsted et al., 2002). This test provides a little more information about the athlete’s balance status; it is also very cost-effective using very little equipment. It has yet to be determined if this test provides enough information to aid in making return to play decisions when balance has been affected.

Other subjective tests include hop tests, balance beam walking, or timed agility tests. The majority of these tools measure either the time to fall, distance walked (eyes open or eyes closed), or time to completion, which provides useful information in determining progress of the athlete but as a measure of proprioception or balance it fails to give quality information about the athlete’s status (Guskiewicz & Perrin, 1996).

**Objective Tests to Measure Balance**

The Balance Error Scoring System is one of the less expensive ways of objectively measuring balance. It is performed using 6 testing conditions, 3 on a hard surface and 3 on a foam surface (Broglio, Zhu, Sopiarz, & Park, 2009; Onate, Beck, & Van Lunen, 2007). The 3 different tests are done with the subject standing on two legs, one leg, and tandem (heel to toe) all tests are done with the subjects eyes closed and last for 20. The clinician then counts the amount of “errors” in balance that occur during each condition. The “errors” are based on a specific set of guidelines that aid the clinician in determining the score. This test is very useful as a “side-line” evaluation of balance following an injury when other equipment is not readily available.

The Chattex Dynamic Balance System is a force platform that measures static and dynamic balance (Mattacola, Lebsack, & Perrin, 1995). It involves a double leg stance
and a single leg stance to determine static balance and then the platform tilts anteriorly and posteriorly 4° to determine dynamic balance. The equipment measures the amount of postural sway using the sway index, the center of balance which also shows postural sway, and the force produced by each foot and by the anterior and posterior portions of each foot. This information also aids in determining the center of balance. On a single leg condition the force plates measure the forces produced by four quadrants of the foot separated anteriorly and posteriorly, then also medially and laterally. All of the measurements that are recorded are then used to form a more well-rounded balance assessment.

The Biodex Medical System uses a platform that has an unstable surface and it has the ability to tilt in any direction much like a BAPS board (Guskiewicz & Perrin, 1996). The Biodex system is used to determine neuromuscular control in maintaining dynamic postural stability (Perron, Hebert, McFadyen, Belzile, & Regnieare, 2007). This system measures the subject’s ability to control the tilt of the platform, a large amount of tilt correlates to a poor muscle response (Guskiewicz & Perrin, 1996). The Kinesthetic Ability Trainer is very similar to the Biodex system it also uses a platform that is placed on a small pivot so that it can tilt in every direction (Surenkok, Aytar, Tuzun, & Akman, 2008). A tilt sensor is located on the platform and is connected to a computer that records the amount of tilt during the test (Guskiewicz & Perrin, 1996; Surenkok et al., 2008). Using the information and how much deviation occurred during the test the computer system cumulates a score which is called the Balance Index (Surenkok et al., 2008).
A basic force plate can be used to measure a wide variety of balance components, the main measurements that are generally used are the center of pressure (COP) and the sway index. This can include standard deviation, path length or mean velocity of the COP (Karlsson & Frykberg, 2000). These measurements of COP have been highly correlated to the center of mass (COM) measurements and so usually both are analyzed. The horizontal ground reaction force is calculated using the horizontal COM acceleration because it is a proportional relationship between COM and COP (Karlsson & Frykberg, 2000). The horizontal force statistical measures have been used to quantify the postural stability (Karlsson & Frykberg, 2000). This measurement is only reliable if you have that person’s baseline results and you can compare them to their own previous data. It is difficult to determine if a person’s results are normal or abnormal based on these calculations. The force plates can also be used to determine general ground reaction forces, weight symmetry, and limits of stability (Guskiewicz & Perrin, 1996).

Neurocom® has designed technology that is able to objectively measure balance and isolate all three components of balance (Guskiewicz & Perrin, 1996). This technology was designed to measure both static and dynamic balance and have been found to have very reliable and valid results. The main tests of focus for this research include the Sensory Organization Test (SOT), Adaptation Test, and Motor Control Test.

**Neurocom Balance System**

The Neurocom Balance System is a means of measuring and analyzing a person’s postural stability (Guskiewicz & Perrin, 1996). This system allows for static and
dynamic measurements as well as double or single leg analysis. It is equipped with a moving surround wall and a moving floor platform that aid in isolating specific balance components. The force plate that is in the floor is capable of rotational as well as translational movements, the force plate then measures the amount of force that is exerted through the feet and can also measure center of gravity and postural control (onbalance.com/products, 2011).

For this study three tests were utilized, the Sensory Organization Test (SOT), the Motor Control Test (MCT), and the Adaptation Test (ADT). The SOT detects any abnormalities in either the visual, vestibular, or somatosensory aspect of balance (Neurocom, <www.onbalance.com>). It also shows which balance strategy was used, either ankle dominant strategy or a hip dominated strategy. The Motor Control Test assesses the ability of the automatic motor system to recover following an unexpected movement of the force platform that the patient is standing on. It measures the latency, which is the amount of time that passes between the platform moving and the reactive muscle contraction to the translation. The Adaptation test shows the force that is required to maintain balance and decrease body sway in respond to the floor being moved unexpectedly and in a rotational way.

Conclusion

This study will focus on specific cases where an athlete was injured and their proprioception will be monitored as they progress back into soccer, and will be compared to their baseline proprioception testing. It has yet to be determined if there is a specific
amount of proprioception that must be regained before allowing an athlete to participate, this study is simply going to monitor an athlete’s proprioception based on the clinicians return to play decisions. Being able to utilize new technology such as the Neurocom, may aid the athletic trainers, physicians, and other clinicians in determining when an athlete should be able to return to playing status as safe and as quickly as possible.
CHAPTER III
METHODOLOGY

The purpose of this study is to determine the amount of balance and postural stability that is negatively affected due to a lower extremity injury and how the athlete’s balance and stability progresses throughout the rehabilitation process. This is going to be accomplished by tracking the balance and postural stability of athletes following an injury until two weeks after they have returned to full competition.

Procedures

The equipment that was used was the Neurocom Smart Balance Master, three specific tests from that equipment were utilized, the Sensory Organization Test, Motor Control Test and the Adaptation Test. All the tests were performed in the Utah State University Athletic Training Room, by the researcher. All of the athletes performed a baseline testing prior to the beginning of preseason. The subjects were required to remove their shoes and socks and had their height measured prior to the testing. Athletes were fitted into a harness, stepped onto the platform, secured the harness to the platform and had their feet positioned correctly, and then began the testing. The tests were administered according to the procedures set in place by the Neurocom Company, giving athletes only the verbal cues that appear on the screen. This procedure was replicated for each athlete who sustained an injury in season (as soon as they were able to bear weight) to determine if there was a balance and postural stability deficit present. Athletes were then retested the day they returned to full participation and then again two weeks after
they returned to participation. The criteria for returning an athlete to full participation were based on the decision of either the athletic trainer or the team physician, following functional progression testing. The following measurements were taken and analyzed to assess balance and postural stability:

- Equilibrium - how well the patient's sway remains within the theoretical limits of stability.
- The sensory analysis - isolating each of the three components of balance and determining how well the patient utilizes each one, and measures their ability to process inaccurate information.
- The ankle/hip dominance - how the patient perceives their stability, if they feel they are more stable they will utilize the ankle strategy and if they perceive they are less stable they will use the hip strategy. This becomes a continuum and scores will be somewhere in between those two opposites.
- The center of gravity (COG) alignment - the degrees of sway in every direction from the center of the force plate.
- The latency during translation - the time (msec) from the force plate moving (forward or backward) to the initiation of an active force response in the legs or the center of force “take off” point.
- Amplitude scaling - the strength of the motor response that is measured during the translation latency, this is to determine if the forces are equal in both legs.
- Sway energy - the amount of force used for the two seconds following rotation of the platform, should decrease each trial due to adaptation.
• Weight symmetry - based on a scale around 100 which indicates that both legs are bearing equal weight, more than 100 means the patient bears more weight on their right leg and less than 100 means more on the left leg.

• Strength symmetry - based on a scale around 100, where 100 means both extremities have the same strength, greater than 100 means the right leg is stronger and less than 100 means left leg is stronger.

• Adaptation - magnitude of the force response required to overcome sway induced by sequences of Toes Up and Toes Down rotational disturbances

Participants

The subjects used for this research were Division I female soccer athletes from the research institution, ages 17-21. During pre-season each athlete practiced 12-16 hours each week and during the regular season practiced approximately 8-10 hours a week, not including games. The number of games differed each week depending on their schedule and the amount of playing time for each person, in regular season they either played 1 or 2 games per week. The criterion for inclusion was that the athlete had obtained a lower extremity injury during the competitive season and had to have an injury that would allow them to return during that competitive season. In order for it to be considered an injury the athlete had to report it to the athletic trainer and also the injury had to required treatment and/or rehabilitation for more than one day. Athletes were excluded from this study if they only required one day of treatment, the researcher determined that single day treatments were typically due to soreness and not actual injuries. This study was
approved by the Utah State Institutional Review Board (Appendix A) and all participants completed an informed consent form that was also approved by the Utah State University Institutional Review Board (Appendix B).

**Review of Cases**

**Case 1.** Subject 1 was a 20-year-old female, and prior to the injury she was a starting defensive center midfielder. Athlete obtained a right knee injury during practice, due to a twisting force. She had a history of ACL surgery 8 years before on the same knee, she also had a previous meniscal surgery, scar tissue removal surgery, and obtained an ACL sprain on the injured knee. She reported feeling her knee shift and was unable to place her full body weight on the affected leg. Upon further exam she had significant pain along the medial joint line, swelling inside the joint, decreased ROM, decreased strength, positive Lachman’s test (compared to her other knee), positive anterior drawer test (compared to the other knee), positive McMurry’s test, negative posterior drawer test, negative valgus stress test, negative varus stress test, and negative Appy’s compression test, all other findings were insignificant. She was placed on crutches with a compressions wrap, was given NSAIDs and was instructed to ice at home multiple times that night. The following day she got an MRI on her knee and the diagnosis was a medial meniscus tear that would require surgery for her to be able to play effectively. Nine days after the injury she got a meniscus resection surgery where the torn piece of meniscus was removed. She was able to walk on that leg two days following her surgery and began physical therapy that same day. Physical therapy followed a traditional program (Appendix C) including ROM exercises, strength exercises, aquatic therapy, balance and
proprioception exercises, running, agility, and speed exercises. Four weeks after the surgery she was cleared to start soccer drills and progress back into playing, she also continued with physical therapy for three more weeks after being cleared to play. As she returned to soccer she started with non-contact soccer drills, then contact with restricted playing time and finally returned to full participation with no restrictions. She returned very well following this injury and returned to her starting position on the team.

**Case 2.** Subject 2 was a 21-year-old starting forward; she obtained a right knee injury during the first game of the season. Athlete had a history of an MCL sprain 3 years earlier on the same knee. She received a valgus force from another player’s knee during the game and jogged off the field. Upon evaluation the athlete had some decreased range of motion, decreased strength, no swelling, tender to palpation along medial collateral ligament and pes anserine, a positive valgus test, with a large amount of laxity, but very little pain, negative lachmans test, negative anterior drawer test, negative posterior drawer test, negative varus test, negative McMurry’s test, negative appley’s compression test, and no other significant findings. She was diagnosed with a grade 3 MCL sprain. She was placed in a brace locked at 30° for the next 4 days removing it only to do some light range of motion. On the fourth day the brace was unlocked but she was still instructed to wear it while walking, she then began rehabilitation (Appendix C) focusing on regaining ROM, strength, proprioception, agility and maintaining conditioning using aquatic therapy. Athlete responded very well to rehabilitation, she was running straight ahead 11 days after the injury, and progressed to agility drills during the third week. She was able to return to practice four weeks later, wearing a custom derotational knee brace.
Case 3. Subject 3 was a 19-year-old, who was a starting forward prior to obtaining a left ankle injury during the eighth game of the season (approximately the middle of the season). She jumped to head the ball and landed on one foot and fell down, when she tried to get up she couldn’t put any weight on the affected leg. She was helped off the field and upon further evaluation she had no visible swelling, decreased range of motion in all directions and decreased strength in all directions; she was tender to palpation along the fibula above the joint and also on the sinus tarsi. Athlete was in a considerable amount of pain, no tests were positive for joint laxity, and there were no other significant findings. She was put on crutches because it was too painful to place weight on it. She got an x-ray the next day and it was negative for a fracture, for the next week she was involved in a rehabilitation program that included aquatic workouts and other non-weight-bearing activities. After that week she was still unable to put weight on the injured ankle without pain. Athlete then got an MRI and it showed that she had significant swelling in her subtalar joint. She was on crutches for another week while performing aquatic workouts to keep her non-weight bearing. After 2 weeks she began some weight-bearing exercises as tolerated, and she began some land running and some light agility exercises. After the third week she was able to progress to non-contact drills in practice as long as she remained pain free, she returned to full participation and back in the starting lineup at the end of the third week.

Case 4. Subject 4 was a 20-year-old defender, who was a non-starter. She obtained a left ankle injury the first day of preseason; she was able to hop off the field and had immediate swelling proximal to her lateral joint along the fibula. Further evaluation showed significant pain, full range of motion in all directions but decreased
strength in all directions, evaluation also showed a positive anterior drawer test, positive
talar tilt test, positive bump test, and negative squeeze test, and no other significant
findings. Athlete was placed on crutches, a compression wrap was applied to the ankle,
and athlete was given NSAIDs with instructions to ice multiple times that day. The next
day the athlete got an x-ray which was negative for a fracture, and was diagnosed with a
grade 2 lateral ankle sprain, that same day she began rehabilitation. Rehabilitation
involved ROM exercises, strength exercises, aquatic rehabilitation, proprioception and
agility exercises (Appendix C). Athlete was returned to play six days later and was taped
and braced to protect the joint. She continued rehabilitation for 2 more weeks and the
focus then was agility and proprioception to reduce the risk of re-injury.

Case 5. Subject 5 was a 17-year-old forward, who was a non-starter because she
was a freshman and was injured during pre-season. She obtained a right ankle injury the
first week of preseason. She felt her ankle plantar flex and invert as she rolled over top of
it; she finished practice before reporting it to the athletic trainer. Upon evaluation athlete
had pain with palpation on the sinus tarsi and along the calcaneofibular ligament, some
decreased range of motion was present in dorsiflexion and plantar flexion, had decreased
strength in dorsiflexion and eversion, swelling was present, positive anterior drawer test,
positive talar tilt test, negative bump test, negative squeeze test, all other findings were
insignificant. The injury was diagnosed as a grade 2 lateral ankle sprain. Athlete was put
on NSAIDs, a compression wrap was applied and she was instructed to apply ice multiple
times a day. Rehabilitation was initiated the following day, which involved regaining full
ROM and strength, proprioception exercises, cutting and agility (Appendix C) as she
progressed back into playing with taping and bracing to protect the joint. She was able to
return to practice four days later but continued with rehabilitation, specifically proprioception, agility and speed exercises for four weeks following return to play. Throughout the season the athlete continued to struggle with reinjuring the ankle. Athlete obtained an x-ray midway through the season and it was normal, she then got an MRI of her ankle and it confirmed the diagnosis of a grade two ankle sprain, with a small split tear of her peroneal muscle, but everything else was normal. Athlete was able to play through re-injuries with taping and bracing, and did not miss any more time throughout the season. After the season ended, she was instructed to take 6-8 weeks off to allow her ankle to heal, then she progressed back to running and then into soccer drills. She still was reporting pain with playing and reinjured her ankle 2 weeks into the spring season. She was referred to a foot and ankle specialist to get a second opinion. He suggested surgery to reconstruct her ankle, which involves dropping the head of her first metatarsal and moving her calcaneus medially. The rehabilitation process following the surgery was approximately 6 months, so there was no further evaluation of the athlete that was included in this research.

Case 6. Subject 6 is a 20-year-old starting defender, who received a left ankle injury after jumping to head the ball on a corner kick and landing on another player’s foot as she landed. The athlete was able to finish the game (approximately 20 minutes left). Upon evaluation she had full strength and full range of motion, positive swelling, had a positive anterior drawer test and some laxity with the talar tilt test, negative bump test and negative squeeze test, there were no other significant findings. The athlete was diagnosed with a grade 2 lateral ankle sprain and was sent home with NSAIDs, her ankle wrapped, and was instructed to ice that evening multiple times. The next morning her
ankle was still swollen but she had full strength, she was instructed to stay off it as much as possible and continue to ice it throughout the day, while keeping it wrapped. The next day was a game day, so she was put through some agility and hop testing to see if the ankle was stable and to help determine if she would be able to play. She said she felt stable during all the tests and she passed them with relatively little pain. She was able to play with her ankle taped and braced. She was put on a rehabilitation program specifically focusing on strength, proprioception/stability exercises as well as agility and speed exercises (Appendix C). She was able to continue playing on it and did not have any complications for the rest of the season.

**Case 7.** Subject 7 was a 20-year-old backup goalkeeper who obtained a right groin injury during practice, while diving to save a shot. Upon initial evaluation she stated she felt the muscle “pull” and had a slight altered gait. Her affected adductor strength was a 4/5, and her pain was initially a 6/10, but decreased by the end of practice to 2/10, no swelling or bruising was present, and there were no other significant findings. Athlete returned to practice the next day on limited status, meaning she was not allowed to dive. Athlete was required to wrap her groin for practice for the next two weeks, as well as placed on a rehabilitation program for the next three weeks to decrease the chance of reinjuring the affected area (Appendix C). Athlete responded very well to the treatment and was back to participation with no restrictions in 2 days.
Data Analysis

Due to the nature of the case study format there were no statistical tests run on each subject, however for each of the above variables that were measured the percentage of change from baseline was identified. Since the Neurocom system is new to the market there are no reliability tests done for the Motor Control Test (MCT) or the Adaptation Test (ADT). The Sensory Organization Test (SOT) has a reliability test that showed a significant increase or decrease if levels varied by ±1.645. Because of this result each variable on the SOT (Equilibrium and Strategy) that was decreased by 1.645% or more was identified, but each variable on the MCT and ADT that showed a 2% decrease was identified, to provide more of a test-retest variance since the reliability of those two tests is unknown. Results that also were decreased by 10% or more were also identified; this provided three levels for the variables that fell below baseline. The levels were 0%-1.645% (SOT), 0%-2% (MCT and ADT), 1.645%-10% (SOT), 2%-10% (MCT and ADT) and >10%.
CHAPTER III

RESULTS

Case 1

Weight Bearing Pre-Surgery

Following the right meniscus tear, once the athlete was weight bearing, the subject’s equilibrium scores on the SOT were decreased in all conditions by 5.9%, 3.1%, 1.4%, 8.8%, 1.7%, and 1.8%. During condition 1 and 3 the athlete’s results dropped below the “normal” levels. She also had a shift from an ankle dominated strategy to a hip dominated strategy in condition 1 (2.4%), condition 3 (2.1%), condition 4 (1.1%) and condition 6 (1.9%), while shifting towards an ankle dominant strategy during conditions 2 (0.7%) and 5 (0.8%). The center of gravity shifts following the injury, before surgery the center of gravity shifted to the unaffected leg. This was also evident on the MCT test as the weight symmetry moved from equally distributed and shifted to the left by 8.5% towards the unaffected leg; the shift resulted in an “abnormal” score, during backwards translation. The latency scores decreased by 2.6% in the left leg and decreased by 3.9% in the right leg. Amplitude was affected the most immediately following the injury increasing in the left leg by 25% and in the right leg by 25.8%. On the ADT the magnitude of force increased by 7.7% following injury during the toes up condition and by 27.7% during the toes down condition.
Weight Bearing Post-Surgery

Once the athlete was weight bearing after surgery was performed, her equilibrium increased during conditions 1 (4.8%), 2 (1.4%), 3 (1.8%) and 4 (0.8%), compared to her weight bearing results before the surgery. On conditions 5 and 6 the scores decreased by 15.7% and 13.2%, respectively. The strategy that was used increased during condition 1 by 4.5%, condition 2 by 1.0%, condition 3 by 4.3% and condition 4 by 1.1%, but decreased on condition 5 by 3.1% and remained the same on condition 6. The center of gravity followed the weight symmetry variable which shifted by 9% back to equal weight distribution. The latency decreased in the left leg by 2.8% but increased in the right leg by 2.6%. The average amplitudes between the pre-surgery and the post-surgery testing decreased 25% on the left leg and 56% on the right leg. Strength symmetry also shifted following surgery by 9.7%, towards the left (unaffected) leg. The ADT showed a decrease in magnitude of force during both the toes up condition (7.7%) and the toes down condition (27.7%).

Return to Participation

As the athlete was cleared to return to play her equilibrium scores increased during conditions 1 (1.0%), 2 (1.4%), 3 (0.7%) and 5 (13.4%), while decreasing during conditions 4 (11.1%) with one trial falling below the “normal” limits, and 6 (2.4%). The strategy used decreased during condition 1 by 2.0%, condition 2 by 0.7%, condition 4 by 6.2% and condition 6 by 4.1%, while increasing in condition 3 by 1.0% and condition 5 by 5.7%. Weight symmetry moved from normal to placing more weight on the injured leg, shifting to the right by 8.5%. The latency increased by 2.7% in the left leg and by
2.6% in the right leg. Amplitude decreased in the left leg by 6.7% and increased in the right leg by 16.7%, as strength symmetry shifted by 13.1% towards the affected leg. On the ADT, the average magnitude of force decreased during the toes up condition by 1.0% and increased during the toes down condition by 22.2%.

Comparing the subject’s equilibrium when she was cleared to return to participation with her baseline results showed her equilibrium was below baseline during condition 1 by 0.3%, condition 2 by 0.3%, condition 4 by 17.3%, condition 5 by 4.3%, and condition 6 by 16.8%, but was above baseline during condition 3 by 1.1%. The strategy used during testing showed condition 1 returned to baseline, with condition 2 (1.0%), condition 3 (3.1%), and condition 5 (3.4%) were utilizing the ankle dominant strategy more than baseline, but condition 4 (6.2%) and condition 6 (6.2%) were using the hip dominant strategy more than baseline. Weight symmetry shifted to the right compared to baseline by 9.0% and strength symmetry shifted right by 3.7%. The latency decreased by 2.7% in the left leg, but increased in the right leg by 1.3%. The amplitude decreased in the left leg by 6.7% and in the right leg by 3.3% compared to baseline, with adaptation decreasing during the toes up condition by 1.0% and increasing during the toes down condition by 22.2%.

**Two Weeks Post Return to Participation**

Two weeks following return to full participation the subject’s equilibrium scores decreased during conditions 1 (0.7%) and 2 (1.1%), but increased during conditions 3 (2.4%), 4 (10%), 5 (1.8%) and 6 (11.2%). The strategy scores stayed the same during conditions 1 and 5, decreased during condition 3 by 0.3%, and increased during condition
2 (0.3%), condition 4 (5.8%) and condition 6 (8.3%). The subject’s weight symmetry returned to 99.5 with 100 being equal weight distribution. The latency increased in the left leg by 2.6%, but decreased in the right leg by 1.3%. Amplitude increased in the left leg by 6.3% and in the right leg by 3.2%, while strength symmetry shifted to the left by 3.8%, compared to scores of when the athlete returned to full participation. The ADT scores two weeks after return to play showed an increase during the toes up condition by 1.0% and showed a decrease during the toes down condition by 25.7%.

Comparing the last data from 2 weeks after returning to play to the baseline data, the equilibrium scores were decreased during condition 1 by 1.0%, condition 2 by 1.4%, condition 4 by 8.8%, condition 5 by 2.6%, and condition 6 by 6.7%, the equilibrium had increased during condition 3 by 3.5%. The strategy used remained the same during conditions 1 and 4, while increasing during conditions 2 (1.4%), 3 (2.7%), 5 (3.4%) and 6 (2.6%). The averages on the MCT and the ADT for two weeks after return to play compared to baseline were both identical.

Case 2

Weight Bearing

Following the injury the subject’s equilibrium increased in conditions 1 (0.7%), 3 (1.1%), 4 (33.5%), 5 (2.1%), and 6 (21.3%), while decreasing in condition 2 by 2.8%, and condition 3 by 1.4%, and moved towards ankle dominance in condition 4 by 9.6%, condition 5 by 3.5% and condition 6 by 11.7%. Athlete’s center of gravity shifted to the
left (away from the affected leg) following the injury. The MCT showed a shift in weight symmetry towards the left leg by 14.6%, and a shift in strength symmetry to the left leg by 9.7%. Amplitude increased in the left leg by 36% and in the right leg by 17.4%, while latency decreased in the left leg by 18.7% and in the right leg by 11.0%. The adaptation decreased by 22.1% during the toes up condition and decreased by 23.9% during the toes down condition.

**Return to Participation**

The equilibrium scores when the athlete was cleared to return to full participation compared to when she was injured decreased in conditions 1 (3.6%) and 4 (4.0%), but increased in conditions 2 (2.8%), 3 (5.3%), 5 (5.3%), and 6 (1.6%). The strategy utilized increased towards ankle dominance in condition 1 by 1.0%, condition 2 by 1.7%, condition 3 by 2.4%, condition 5 by 4.1%, and moved towards hip dominance in conditions 4 (0.4%) and 6 (3.5%). Center of gravity and weight symmetry moved towards equal distribution, weight symmetry shifting by 9.9%. Strength symmetry shifted towards the left leg by 9.5%, while amplitude decreased on the left leg by 47.8% and on the right leg by 80%. The latency decreased in the left leg by 2.8% and increased in the right leg by 6.4%. Adaptation decreased during the toes up condition by 6.5% and increased during the toes down condition by 2.6%.

Comparing the subjects scores when she returned to play with her baseline testing showed that her equilibrium decreased in condition 1 by 2.8%, returned to baseline in condition 2, and increased in conditions 3 (6.8%), 4 (28.4%), 5 (7.8%) and 6 (23.3%). The strategy utilized showed that during condition 1 the strategy returned to baseline with
a shift towards ankle dominance during conditions 2 (0.7%), 3 (1.0%), 4 (8.5%), 5 (7.3%), and 6 (7.4%). Weight symmetry shifted to the left by 5.1%, with strength symmetry also shifting left by 17.6%. Latency decreased in both the left leg (20.9%) and in the right leg (4.9%). Amplitude decreased in the left leg by 8% and in the right leg by 34.8%, and the adaptation decreased in both the toes up condition (27.2%) and the toes down condition (21.9%).

Two Weeks Post Return to Participation

Two weeks following the subject’s return to full participation her equilibrium increased in condition 1 by 3.2%, condition 4 by 0.8%, and condition 5 by 5.9%, while decreasing in conditions 2 (2.6%), 3 (1.8) and 6 (9.5%). The strategy used moved towards ankle dominance in condition 1 by 1.7%, condition 2 by 0.7%, condition 3 by 1.0%, condition 4 by 1.1%, and condition 5 by 2.0%, but moved towards hip dominance in condition 6 by 4.1%. The weight symmetry moved towards equal distribution by 0.2% and strength symmetry moved towards equal strength by 14.8%. Latency increased in the left leg by 0.2% and remained unchanged in the right leg. Amplitude increased in the left leg by 8.0% and in the right leg by 34.8%, while adaptation increased during the toes up condition by 1.5% and in toes down by 4.5%.

The final testing, when compared to baseline, showed that the equilibrium increased in condition 1 by 0.4%, condition 3 by 4.7%, condition 4 by 22.7%, condition 5 by 12.7% and condition 6 by 11.2%, but decreased in condition 2 by 2.6%. The strategy that was used moved towards ankle dominance in all conditions by 1.7%, 1.4%, 2.0%, 9.5%, 9.2%, and 3.6% respectively. Weight symmetry moved closer to equal
distribution, shifting left by 5.2% and strength symmetry moved towards the left leg by 3.4%, while amplitude remained the same. The latency showed a decrease in the left leg by 16.7% and in the right leg by 5.1%. The adaptation decreased by 26.1% during the toes up condition and by 18.4% during the toes down condition.

Case 3

Weight Bearing

The subject’s equilibrium that was measured immediately following the injury stayed the same during condition 1 then increased in condition 2 by 3.0%, condition 3 by 4.1%, condition 4 by 12.4%, condition 5 by 5.1% and condition 6 by 3.0%. The strategy that was utilized decreased in the first two conditions by 1.4% in each, it increased during condition 3 by 1.0%, condition 4 by 2.5% and condition 5 by 2.4%, in condition 6 it decreased by 0.4%. The center of gravity shifted following injury to the right, away from the affected leg. This is also evident in the weight symmetry that shifted to the right leg as well after the injury by 11.3%. The average latency remained the same in the left leg and decreased in the right leg by 2.4%. The amplitude on the left leg decreased by 35.7% and increased on the right leg by 17.4%. The strength symmetry shifted to the right as well by 22.4%. The adaptation showed that during the toes up condition the average decreased by 5.8% and during the toes down condition it increased by 1.0%.
Return to Participation

Comparing the results from after the injury to when the athlete was cleared to return to participation the equilibrium increased in conditions 1 (1.0%, 2 (1.1%) and 6 (4.7%), while decreasing in conditions 3 (2.2%), 4 (4.9%) and 5 (0.8%). The strategy that was used increased in condition 1 by 2.0%, condition 2 by 2.0%, condition 3 by 1.0%, condition 5 by 1.5% and condition 6 by 2.6%, while decreasing in condition 4 by 1.8%. The subject’s center of gravity shifted back to the left to a more neutral location. Along with that the weight symmetry shifted back to the left by 3.6%, as well as strength symmetry shifted to the left by 16.9%. The latency score decreased in the left leg by 2.4% and increased in the right leg by 2.4%. Amplitude in the left leg increased by 35.7% and decreased in the right leg by 8.7%. The adaptation decreased in the toes up condition by 18.8% and in the toes down condition by 11.2%.

When the subject was cleared to return to participation compared to her baseline scores her equilibrium had increased in all conditions by 1.0%, 3.9%, 1.8%, 6.7%, 4.1%, and 7.5% respectively. The strategy used moved towards ankle dominance compared to baseline in all conditions by 0.7%, 0.7%, 2.0%, 0.7%, 3.8%, and 2.2% respectively. Weight symmetry shifted to the right by 8.0%, and strength symmetry also shifted right by 6.5%. The latency decreased in the left leg by 2.4% and remained the same in the right leg. The amplitude returned to baseline in the left leg and increased in the right leg by 9.5%, while adaptation decreased during the toes up condition by 23.5% and during the toes down condition by 10.3%.
Two weeks following the full return to participation the athlete’s equilibrium decreased in condition 1 by 0.7%, then increased in conditions 2 (1.8%), 3 (3.9%), 4 (1.8%), 5 (3.9%) and 6 (3.1%). The strategy that was used decreased in conditions 1 (1.7%), 2 (0.3%) and 3 (0.7%), and increased in condition 4 by 0.7%, condition 5 by 3.3% and condition 6 by 1.8%. Weight symmetry shifted to the left by 5.4% and strength symmetry shifted to the left by 7.5%. Amplitude in the left leg decreased by 5.3% and in the right leg by 19.0%, while latency increased in the left leg by 3.6% and decreased in the right leg by 5.9%. The average adaptation increased in the toes up condition by 4.0% and remained the same during the toes down condition.

The baseline test compared to the test results from two weeks following return to participation showed that the equilibrium increased in all conditions by 0.3%, 5.6%, 5.7%, 8.5%, 7.9% and 10.3% respectively. The strategy utilized showed that during condition 1 the strategy shifted towards hip dominance by 1.0%, while the rest of the conditions shifted towards ankle dominance by 0.3%, 1.4%, 1.4%, 7.0%, and 4.0% respectively. Comparing the weight symmetry at baseline with the end result showed a shift towards equally distributed weight by 2.7%, strength symmetry moved to the left leg compared to baseline by 1.0%. The latency score increased in the left leg by 1.2% and decreased in the right leg by 6.3%, while the amplitude decreased in the left leg by 5.6% and in the right leg by 11.8%. Adaptation was decreased by 20.4% in the toes up condition and by 10.3% in the toes down condition.
Case 4

Weight Bearing

Subject 4 had an increase in equilibrium, following her injury compared to baseline, during conditions 1 (8.3%), 2 (4.2%), 3 (6.5%), 4 (14.2%) and 5 (2.4%), while decreasing during condition 6 (6.0%). The strategy that was used showed a decrease during conditions 2 (2.4%), 3 (5.2%) and 5 (5.6%), as well as an increase in conditions 4 (1.2%) and 6 (4.6%), and no change in condition 1. Center of gravity following the injury shifted to the right, away from the affected leg. The weight symmetry measured on the MCT, showed a slight shift to the left by 1.4%, while strength symmetry remained the same. The average latency score decreased by 1.3% in the left foot and by 16.8% in the right leg. Amplitude also decreased by 25.9% in the left leg and 26.9% in the right leg. The adaptation decreased in both toes up (13.2%) and in toes down (4.9%).

Return to Participation

As the athlete was returned to participation, her equilibrium decreased in conditions 1 (7.3%), 2 (2.2%) and 4 (3.1%), but increased during conditions 3 (2.0%), 5 (5.1%) and 6 (4.9%). The strategy that was used decreased in conditions 1 (2.4%), 4 (0.4%) and 6 (4.0%), while increasing in conditions 2 (0.7%), 3 (3.3%) and 5 (11.4%). The subject’s center of gravity shifted back to the right; however her average weight symmetry shifted to the left by 3.2%. The latency decreased in the left leg by 6.5% and increased in the right leg by 5.1%. The amplitude stayed the same on the left leg, but increased by 21.1% on the right leg. Strength decreased 6.6% away from equal strength
towards the right leg. The adaptation decreased during the toes up condition by 16.3%, but increased during the toes down condition by 15.4%.

Comparing the subject’s baseline data to when she returned to participation showed the equilibrium increased in condition 1 by 0.4%, condition 2 by 1.9%, condition 3 by 8.0%, condition 4 by 9.6%, and condition 5 by 7.0%, while decreasing in condition 6 by 1.4%. The strategy used showed a shift towards hip dominance in condition 1 by 2.4%, condition 2 by 1.7%, and condition 3 by 2.1%, but a shift towards ankle dominance during condition 4 by 0.8%, condition 5 by 5.2% and condition 6 by 0.4%. Weight symmetry shifted to the left by 4.5% and strength symmetry shifted right by 6.5%, while amplitude decreased in the left leg by 25.9% and in the right leg by 11.5%. The latency decreased in the left leg by 7.8% and in the right leg by 12.6%. The ADT showed the magnitude of force during adaptation decreased during the toes up condition by 27.4% and increased during the toes down condition by 9.8%.

**Two Weeks Post Return to Participation**

Once the athlete had been cleared to return to full participating for two weeks she was retested and her equilibrium increased in condition 1 by 0.4%, condition 4 by 5.7%, condition 5 by 9.6% and condition 6 by 10.8%, at the same time it decreased in condition 2 by 0.4% and condition 3 by 4.6%. The strategy that was utilized to achieve balance also increased in condition 1 by 1.4%, condition 4 by 2.6%, condition 5 by 2.0% and condition 6 by 4.8%, it remained the same during condition 3 and decreased during condition 2 by 0.3%. Weight symmetry shifted to the left by 0.4%, and strength symmetry shifted to the left by 12.0%. The latency in the left leg increased by 13.9% but
decreased in the right leg by 3.6%, while the amplitude in the left leg remained the same, but in the right leg decreased by 21.7%. The adaptation decreased during both toes up (4.8%) and toes down (1.7%).

Comparing the last testing results that were taken 2 weeks after the subject was cleared to participate to the baseline results showed that equilibrium increased in every condition by 0.8%, 1.5%, 3.8%, 14.7%, 15.9%, and 9.6%, respectively. The measurement of the strategy that was used showed a shift towards hip dominance in conditions 1 (1.0%), 2 (2.1%) and 3 (2.1%), but the strategy increased towards ankle dominance in conditions 4 (3.5%), 5 (7.3%), and 6 (5.5%). Weight symmetry decreased by 4.8% away from equal distribution towards the left, strength symmetry also shifted to the left by 6.3% moving away from equal strength. The latency increased in the left leg by 5.1% and decreased in the right leg by 15.8%. Amplitude decreased by 25.9% in the left leg and 30.8% in the right leg. The average magnitude of force measured in the ADT showed that the toes up condition decreased by 30.8% and the toes down condition increased by 7.9%.

**Case 5**

**Weight Bearing**

Following the injury the subject’s equilibrium decreased during condition 1 by 3.9%, condition 2 by 5.0%, and condition 5 by 9.8%, while increasing during condition 3 by 1.9% and condition 4 by 1.2%, but remained the same during condition 6. The strategy used was decreased during conditions 1 (2.4), condition 2 (6.2%), condition 4
(2.3%) and condition 5 (16.5%), while increasing during condition 3 by 2.5% and condition 6 by 1.2%. The center of gravity showed a shift from baseline, leaning more towards the unaffected side. Weight symmetry also shows a shift to the right by 1.7% and strength symmetry shifted to the left by 6.6%. On the MCT, the average latency scores increased in the left leg by 20.8% and in the right leg by 2.6%. The average amplitude increased by 8.6% in the left leg and decreased 9.1% in the right leg. During the ADT test, the toes up average of all 5 trials decreased by 2.9% while toes down average of all 5 trials increased by 18.6%.

**Return to Participation**

Comparing the subject’s results immediately after the injury with when she returned to full participation, the equilibrium increased in all conditions by 1.1%, 0.4%, 1.8%, 5.4%, 15.3%, and 8.7% respectively. The strategy utilized also increased for all conditions by 1.7%, 3.5%, 1.4%, 4.4%, 23.5%, and 3.0% respectively. Weight symmetry shifted to the right by 1.3% while amplitude decreased 14.3% on the left leg and decreased 12.12% on the right leg, and strength symmetry shifted to the left by 1.9%. The average latency remained unchanged in the left leg but increased by 9.3% in the right leg. The ADT showed that during the toes up condition that the subject decreased magnitude of force by 12.26% and during the toes down condition decreased the magnitude of force by 17.19%.

The subject’s baseline equilibrium compared to when she was cleared to return to participation showed a decrease from baseline during conditions 1 (2.9%) and 2 (4.7%), with an increase from baseline during conditions 3 (3.8%), 4 (7.0%), 5 (6.5%), and 6
(9.5%). The strategy used shifted towards hip dominance during condition 1 by 0.7% and condition 2 by 2.7%, while shifting towards ankle dominance during condition 3 by 3.9%, condition 4 by 2.3%, condition 5 by 9.1% and condition 6 by 4.4%. The subject’s weight symmetry shifted to the right compared to baseline by 3.0%, strength symmetry shifted to the left by 8.4%, with amplitude decreasing in the left leg by 6.3% and in the right leg by 19.4%. The latency increased by 20.8% in the left leg and increased by 11.6% in the right leg. The adaptation decreased during the toes up condition by 14.7% and increased during the toes down condition by 1.7%.

**Two Weeks Post Return to Participation**

Comparing the subject’s results from when she was cleared to return to play with two weeks later, her equilibrium increased during conditions 1 (5.2%), 2 (4.7%), 3 (1.1%) and 4 (5.5%, while decreasing in conditions 5 (2.7%) and 6 (0.4%). The strategy that was utilized increased during condition 1 by 2.0%, condition 2 by 2.4%, condition 3 by 0.7% and condition 4 by 2.5%, while decreasing during conditions 5 (2.7%) and 6 (0.4%). Weight symmetry shifted to the left by 2.5% and strength symmetry shifted to the right by 2.11%. The average latency decreased by 6.5% in the left leg and by 15.1% in the right leg. The amplitude of the left foot increased by 21.05% and on the right foot increased by 19.44%. The magnitude of force measured on the ADT decreased in both the toes up condition (7.72%) as well as the toes down condition (2.19%).

The baseline data compared to the end data taken 2 weeks following return to play showed an increase in equilibrium during conditions 1 (2.4%), 3 (4.7%), 4 (11.7%), 5 (3.6%) and 6 (8.3%), with condition 2 remaining the same. When comparing the strategy
utilized, there was an increase during conditions 1 (1.4%), 3 (4.5%), 4 (4.7%), 5 (2.8%) and 6 (2.7%), with a decrease during condition 2 by 0.34%. Weight symmetry showed a shift towards the right by 0.5%, while strength symmetry showed a shift the left by 6.5%. Average latency increased by 15.3% in the left leg and decreased in the right leg by 4.1%. Amplitude in the left leg increased by 15.79% while amplitude in the right leg returned to baseline but did not increase or decrease. Finally the magnitude of force on the ADT was decreased by 21.32% during the toes up condition and by 0.56% in the toes down condition.

Case 6

Weight Bearing and Return to Participation

The subject was tested following the injury but did not miss any playing time so the results compare baseline with post injury then two weeks after the injury. Comparing the results following the injury with baseline showed that equilibrium decreased in condition 1 by 0.7% and condition 4 by 1.1%. Equilibrium remained unchanged in condition 3, but increased in condition 2 by 2.2%, condition 5 by 6.1% and condition 6 by 15.7%. The strategy that was used moved towards hip dominance in condition 1 by 0.3% and moved towards ankle dominance in conditions 2 (7.5%), 3 (1.0%), 4 (0.4%), 5 (0.4%) and 6 (9.2%). The center of gravity shifted to the left compared to baseline, and weight symmetry shifted to the left as well by 2.4%. However, strength symmetry shifted towards the right leg by 22.4%, and amplitude decreased in the left leg by 8.7% and increased in the right leg by 22.7%. The latency remained unchanged in the left leg but
increased by 49.1% in the right leg. Adaptation decreased in both the toes up condition (18.0%) and in the toes down condition (14.4%).

**Two Weeks Post Return to Participation**

Two weeks after the injury the subject’s equilibrium remained unchanged in condition 1, increased in condition 2 by 1.4% and in condition 6 by 9.5%, but decreased in condition 3 by 0.4%, condition 4 by 0.7%, and condition 5 by 0.4%. The strategy utilized remained unchanged in conditions 1 and 4, increased in condition 2 by 0.7% and condition 6 by 1.5%, and decreased in condition 3 by 1.0% and condition 5 by 2.7%. Weight symmetry shifted to the right by 4.6%, while strength symmetry shifted to the left towards equal strength by 6.8%. The latency decreased in the left leg by 3.8%, but increased in the right leg by 1.3%. Amplitude increased in the left leg by 27.6% and in the right leg by 15.6%, and adaptation increased during toes up by 5.4% and toes down by 12.3%.

The subject’s ending test compared with her baseline testing showed that equilibrium decreased in condition 1 by 0.7%, condition 3 by 0.4%, and condition 4 by 1.8%, while increasing in condition 2 by 3.8%, condition 5 by 5.7%, and condition 6 by 27.8%. The strategy used moved towards hip dominance during conditions 1 (0.3%) and 5 (2.2%), strategy remained unchanged in condition 3, but moved towards ankle dominance in conditions 2 (8.3%), 4 (0.4%), and 6 (10.8%). The weight symmetry shifted to the right leg by 2.3% as did strength symmetry by 12.7%. The latency decreased in the left leg by 3.8% and increased in the right leg by 33.8%. The amplitude increased in the left leg by 20.7% and in the right leg by 31.3%, while adaptation
decreased during the toes up condition by 13.3% and during the toes down condition by 2.4%.

Case 7

Weight Bearing and Return to Participation

Subject was injured but did not miss any playing time, so the first results show the comparison from time of injury as well as when she returned to participation. Comparing those results with baseline testing showed that the subject’s equilibrium increased in condition 1 by 1.1% and in condition 2 by 1.4%, staying the same in condition 3, then decreasing in conditions 4 by 5.5%, condition 5 by 22.5% and condition 6 by 9.7%. The strategy being used showed an increase in conditions 1 (0.7%), 2 (7.0%), and 6 (0.4%), and a decrease in conditions 3 (1.0%), 4 (1.5%), and 5 (3.9%). Athlete’s center of gravity moved slightly to the right compared to baseline but was still to the left of normal. Weight symmetry also showed a shift to the right compared to baseline by 3.5%, but was still to the left of equal symmetry. Strength symmetry also shifted to the right by 11.6% but was still left dominated compared to equal strength. Latency decreased in the left leg by 8.1% and in the right leg by 7.8%, while amplitude decreased in the left leg by 20.8% and in the right leg by 23.8%. Adaptation increased in the toes up condition by 0.5% and in the toes down condition by 10.2%.
Two weeks after the injury the subject’s equilibrium decreased in condition 1 and 3 by 0.7% each, it remained constant in condition 2 and increased in condition 4 by 6.2%, condition 5 by 16.4% and condition 6 by 18.3%. The strategy used decreased in condition 1 by 0.7%, remained constant in conditions 2 and 5, while increasing in conditions 3 (0.3%), 4 (2.5%) and 6 (3.6 %). Weight symmetry moved to the left by 0.5% and strength symmetry moved to the right by 1.8%. Amplitude in the left leg decreased by 41.2% and in the right leg by 23.5%, while latency increased in the left leg by 3.9% and in the right leg by 11.5%. The subject’s adaptation decreased in the toes up condition by 14.6% and increased in the toes down condition by 0.5%.

Comparing the subject’s data from two weeks following an injury to the baseline testing showed that the equilibrium increased in condition 1 by 0.3%, condition 2 by 1.4%, condition 4 by 0.7%, and condition 6 by 9.6%, but decreased in condition 3 by 0.7% and condition 5 by 8.0%. The strategy utilized remained the same in condition 1 and increased in condition 2 by 6.5%, condition 4 by 1.1% and condition 6 by 4.0%, but decreased in conditions 3 by 0.7% and 5 by 4.0%. Weight symmetry shifted towards equal distribution by 3.1% and strength symmetry shifted towards equal strength by 13.2%. Latency decreased in the left leg by 3.9% and increased in the right leg by 4.6%. Amplitude decreased in the left leg by 70.6% and in the right leg by 52.9%. Adaptation decreased by 14.1% during the toes up condition and by 8.8% in the toes down condition.
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Note. **Bold** indicates a decrease by more than 2%

*Underline* indicates a decrease of more than 10%
CHAPTER IV
DISCUSSION

Case 1

Weight Bearing Pre-Surgery

Subject 1 initially had a decrease in equilibrium immediately following a right leg meniscus tear and once she was able to bear weight. During condition 1 and 3 she received a score below the “normal” range. This result is significant because the first three conditions utilize the somatosensory aspect of balance. So a decrease in any or all of these conditions should be weighted more than the other conditions, because following the injury the somatosensory should be the only element of balance that is disrupted (Hrysomallis, 2007). The strategy she was using was relying much more on the hip strategy to maintain postural stability instead of relying on an ankle strategy to maintain balance. This follows a natural response to an injury where she is relying on her hip musculature because it is proximal to the injury since her response distal to the injury is likely impeded (Hrysomallis, 2007). One of the bigger concerns on her test post injury was the center of gravity and the weight symmetry scores. On the center of gravity chart it is easy to see that the subject is favoring her right leg and fell below the “normal” range during part of the weight symmetry test. This can affect other scores since she is already unevenly maintaining her postural stability. This subject’s adaptation scores were also increased significantly. That shows that it took much more force to maintain balance during an unexpected movement of the platform than prior to her injury. Knowing that the strategy used shifted towards more hip dominance to maintain balance this subject’s
adaptation should be higher because the muscles at the hip take much more force and movement than the smaller muscles of the ankle.

**Weight Bearing Post-Surgery**

Following the subject’s meniscus resection surgery she had an increase in equilibrium during conditions 1 through 4, but a very significant decrease during conditions 5 and 6 that was compared to post injury results. The strategy utilized for the most part increased towards a more ankle dominant strategy and her weight symmetry normalized. Following the resection of her meniscus it would be easier for her to place weight on the affected leg so it makes sense that her weight symmetry would normalize. Latency measures the reaction time of the muscles in the leg, as they respond to the movement of the platform, in this case following surgery the latency increased in the affected leg and decreased in the unaffected leg. The decrease in the unaffected leg could be due to a learning curve from taking the test multiple times but it is consistent that the affected leg would react slower following surgery. The adaptation decreased meaning that the subject used less force to maintain postural stability compared to when she was initially injured, this is a positive sign showing that the surgery did not set her back at all but was able to improve some of the results by removing and cleaning up the inside of the joint.

**Return to Participation**

As the athlete was cleared to return to participation her equilibrium had increased in almost all conditions compared to post surgery, however they were all still below her
baseline testing. The strategy that she was using to maintain balance was returned to baseline or above during the majority of the conditions. The strength and weight symmetry had actually shifted to the affected leg, so she was placing more weight and was stronger in that leg compared to her baseline. Compared to baseline her latency had decreased in the unaffected leg, and increased in the right but only by a very small amount. The amplitude was decreased compared to her baseline, meaning she was using less force to stabilize following a shift to the platform. The adaptation decreased during toes up meaning the athlete was using less force to stabilize during a rotation of the platform, but was still above baseline during toes down. The majority of the results had improved which is what should occur as an athlete is returned to competition. There were some results below baseline but the athlete was probably able to compensate for those deficits since many of the results had improved from her baseline testing.

**Two Weeks Post Return to Participation**

Two weeks after the athlete had returned to full participation her equilibrium had increased from when she was cleared to return to play, but it was still below her baseline tests. Her strategy that she used was either equal to or moved towards ankle dominance compared to her baseline testing. Her adaptation was relatively the same during the toes up condition but had decreased significantly during the toes down condition compared to when she returned to participation. The results of her toes down adaptation test shows that something might have distracted the athlete during the return to play testing or some other factor might have contributed because her adaptation probably did not improve that much in the two weeks after returning to play. Her strength shifted to the left compared
to when she returned to play, but it returned to exactly where it was on her baseline test. Amplitude and latency also returned to her baseline levels.

Following the progression of this injury it is easy to see how as she was tested throughout the injury that each testing was moving in the right direction, even if one or two measurements were had declined the majority were improving and two weeks after she was returned to participation her MCT and ADT tests were identical. The return to play testing showed some of the results were still below baseline but others had improved significantly from baseline so the athlete might have been compensating to make up for some of the measurements that were not fully returned (Gaerlan, 2010). As the athlete was returned to participation her balance returned to baseline conditions so the measurements that had improved attempting to compensation decreased while others improved back to baseline. This subject had a fantastic outcome, being able to return to baseline or better, and her performance was not affected significantly by the injury as she was able to return to her starting position.

Case 2

Weight Bearing

Subject 2 obtained a grade 3 right MCL sprain; this was the second time she had injured her MCL on this knee so she responded much quicker than someone who had injured their knee for the first time. Following the injury she had an increase in equilibrium in the majority of the conditions, strategy also increased in the last three conditions, showing the athlete was using more ankle dominance to maintain postural
stability during the more complicated conditions. However, during the first three conditions she was using more of hip dominance to maintain postural stability. She had a shift in her center of gravity as well as weight symmetry towards the uninjured leg, which is fairly common that she would be favoring the right leg. This result might affect the strategy she was using as well as the equilibrium scores. She also showed that she had more strength in the left leg compared to the right leg, which is consistent with the physical exam that showed decreased strength in that leg. Latency decreased in both legs as did adaptation during both conditions. These measurements seem like they would increase following an injury, however the athlete’s weight was shifted significantly to the left leg, so the other results might be misleading since the subject is primarily using the uninjured leg to maintain postural stability. This athlete also had experienced this injury before so her body might have been able to compensate better than someone who had been injured for the first time (Starkey & Johnson, 2006).

Return to Participation

As the athlete was returned to participation her equilibrium increased in the majority of the conditions and the strategy being used showed a more ankle dominated strategy in the majority of the conditions. Athlete’s center of gravity had normalized, and subsequently the weight distribution reached equal distribution between the two legs. The strength symmetry was still showing the left leg was stronger. Because the injury was so significant the athlete might not have regain full strength due to the fact that she was probably compensating for the lack of joint stability that was provided by the ligament that was disrupted (Arnheim & Prentice, 2000). The latency was also still
increased in the right leg, and had improved in the left leg compared to following the injury, but compared to baseline results both had improved. The adaptation had decreased during the toes up condition, but required more force to maintain balance during the toes down condition, but when compared to baseline both conditions had improved. The fact that both of these reaction measurements had improved from her baseline results shows that she is able to protect herself during unexpected movements, which is a weighted factor when returning an athlete to participation (Gaerlan, 2010).

Two Weeks Post Return to Participation

Two weeks following the injury the equilibrium overall remained relatively the same compared to when the athlete had returned to play, but compared to her baseline results most of the conditions had improved. The strategy that was utilized had improved in the past two weeks in the majority of the conditions, but compared to baseline testing the subject was utilizing more of an ankle dominated strategy during all conditions. Weight symmetry remained normalized and the strength symmetry was equal between the two legs. Compared to baseline both latency time and the adaptation force had decreased in both legs and in both conditions.

This subject had a very significant injury, and she responded very well to it. It would have been understandable if she was still lacking in certain measurements following the injury because of the tissue damage that had occurred. It is important that athletes who have significant injuries use rehabilitation to regain their previous balance and proprioception and should have it improved compared to their baseline scores in order to reduce the risk of re-injury. Specifically when dealing with knee and ankle
injuries it is important to regain and improve the postural stability because of the forces and stresses placed on those joints during athletic activities.

Case 3

Weight Bearing

Subject 3 had subtalar swelling in her left ankle and missed 3 weeks of competition while she was recovering. Once the athlete was able to bear weight on her ankle, her testing showed that she had an increase in equilibrium, and showed that she was using more of an ankle dominated strategy than her baseline results. These results are slightly contradicting because it would seem that she should have a decrease in these two variables. Her shift towards ankle dominance might be due to the fact that the ligaments and musculature remained relatively uninjured, she had only disrupted the inside of the joint. Since there was little damage done outside the joint perhaps the athlete disrupted less somatosensory receptors, which could be a reason the athlete was able to improve in equilibrium and strategy (Hrysomallis, 2007). She also had a shift in center of gravity and her weight symmetry shifted to the right extremity, away from her injured leg, this shows it was uncomfortable to place weight on the affected leg because of the swelling that was present. Her strength symmetry had also shifted, showing that she was stronger on the right leg compared to the injured leg. Latency showed that she had a decrease in the unaffected leg, but no decrease in the affected leg. Comparing the two legs it shows that she had a higher latency in the injured leg, because both legs should be the same. She had an improvement from the first test to the second in her
uninjured leg, so she should also have the same improvement in the injured leg, but since
that was not the case it shows that she did in fact have a slightly higher latency. This
finding makes sense that she would have had a slower reaction time on the injured leg
because of the swelling that was present (Hopkins & Palmieri, 2004).

Return to Participation
As the subject was returned to competition, half of her equilibrium scores had
increased compared to when she was first injured, but compared to baseline all of her
equilibrium scores had been increased. The strategy that she was utilizing showed an
increase towards ankle dominated strategy, compared to baseline all conditions had been
improved. When returning to play she had a shift from her right leg to her left leg in the
center of gravity and the weight symmetry variables, but also in the strength symmetry
category compared to when she was first injured. These results are very positive, because
it shows that the majority of the swelling had dissipated since the athlete felt comfortable
placing equal weight on the affected leg. However, comparing return to play results to
her baseline results she was still favoring the left leg slightly, as well as strength was also
higher in the right leg. The latency had improved in the injured leg compared to baseline,
showing she had a better reaction time during a shift of the platform. Adaptation had also
decreased, showing that it took the subject less force to adapt to a rotational movement of
the platform. All of these results show a great improvement compared to when she was
first injured but also an improvement on her baseline results. Returning the athlete to
participation with results that are above baseline is the ultimate goal because then she
decreases the chance of reinjuring the affected ankle.
Two Weeks Post Return to Participation

Two weeks after the athlete was returned to full participation her equilibrium had continued to improve compared to when she was returned to participation. Along with that the strategy that she was utilizing continued to improve during the last three conditions moving towards the ankle dominated strategy. The strategy had also improved when compared to her baseline results. The weight symmetry continued to shift to the affected leg, compared to the baseline her weight had shifted to where it was being equally distributed between both legs. Strength also was still shifting to the left, and compared to the baseline she was stronger now in the injured leg. The latency was still increased in the left leg, but had improved in the right leg, but adaptation had decreased in both conditions. The latency did not return to baseline in the injured leg, but because the adaptation had improved compared to baseline the athlete was probably able to compensate for the decreased reaction time because the majority of the other variables had increased by a large amount.

This subject showed a consistent improvement in the unaffected leg during each test. This could be due to some sort of learning curve, since her muscle memory would improve during each test. But following the results from the affected leg it shows a progression throughout the rehabilitation process and even after that. It is a very good example of how an athlete’s postural stability should improve as they are progressing towards return to participation. At the time of return to participation this subject had improved in almost every variable measured so it is no surprise that she did not experience any complications throughout the season. This shows that her results had
improved enough to return her to participation safely and without re-injury for the remainder of the season.

Case 4

Weight Bearing

Subject 4 obtained a left grade 2 ankle injury and following that injury her results showed that she had an increase in equilibrium. This was not very consistent following an injury to the lower extremity; it is hard to determine why these scores were elevated. There could have been a learning curve that occurred from taking the tests more than once, or the fact that her center of gravity during the SOT test was shifted more towards the unaffected leg. Since this test does not differentiate between extremities it is difficult to determine if this was a significant finding. The strategy that was utilized decreased or remained the same in most conditions, showing that the subject was using a hip dominated strategy over an ankle dominated strategy compared to her baseline testing. This finding is consistent with the literature that shows a change in strategy used following an injury specifically to the ankle (Hrysomallis, 2007). Her center of gravity shifted to the right on the SOT test but her weight symmetry shifted to the left on her MCT, compared to her baseline testing. It is difficult to determine why her weight symmetry shifted to the left but it also is evident that she feels comfortable placing weight on the affected leg, which is a good sign. The subject had a decrease in the latency, showing that she had a faster reaction time compared to her baseline testing, as
well as a decrease in the adaptation force required to maintain postural stability during a rotational movements.

**Return to Participation**

As the subject was returned to participation she had an increase in her equilibrium throughout the majority of the conditions. The strategy that she was utilizing showed she was using more of a hip dominated strategy during the easier conditions, but during the more complicated conditions she was using more of an ankle dominating strategy. This is a good sign since the more complicated conditions use more of an instinctive reaction than the easier conditions. The weight symmetry shifted to the injured leg, which is a positive finding showing that she is comfortable placing equal weight on the injured leg. This also shows that when as the platform moves forward or backward it is not painful for her to place more weight on the injured leg, or else she would compensate by taking weight off of that injured body part. Strength symmetry shifted to the right, away from her injured leg, showing that her strength was not fully equal in both legs. The adaptation decreased during the toes up condition but increased during the toes down condition, this could be due to the physiological changes that occurred from the injury.

**Two Weeks Post Return to Participation**

Two weeks following the return to full participation, the subject showed that her equilibrium continued to increase and compared to baseline all conditions were higher. The strategy utilized also increased and half the conditions had returned to baseline levels or above. Weight symmetry had shifted towards the injured ankle meaning the subject
was placing more weight on the injured leg compared to her baseline test. The strength symmetry also shifted to the left, so that compared to baseline her left leg was stronger than the right leg. The adaptation had decreased in both conditions compared to when the athlete had returned to competition. Compared to her baseline results she had improved during the toes up condition, but was still decreased during the toes down condition.

This athlete showed a fairly natural progression throughout the rehabilitation process. A few of her variables were conflicting, such as center of gravity and weight symmetry, these two shifted in the opposite directions which were confusing when reviewing the results. She favored her uninjured leg during the SOT testing and then shifted her weight to the injured leg during the MCT test, this could be due to fatigue or some other variable, but it proves that the athlete was comfortable placing weight on the injured leg. The other variable that was interesting was the adaptation, while the toes up condition improved the toes down condition revealed a slower reaction time. This is due to the nature of an ankle sprain, since typically the anterior and lateral musculature is disrupted due to the injury but the posterior musculature remains uninjured (Hopkins & Palmieri, 2004). The rotational movement when the platform is rotated down, the anterior musculature needs to activate in order to maintain an upright posture. When those muscles are injured (as is the case in the majority of ankle sprains) the reaction force needed should increase to compensate for the injured structures. During the toes up condition the posterior musculature which is usually intact after a grade 2 lateral ankle sprain should remain at baseline levels.
Case 5

Weight Bearing

Reviewing the subject’s results following her right grade 2 ankle sprain it is obvious that equilibrium decreased. She was also using the hip dominated strategy more than her baseline testing. This is consistent with the disruption of the somatosensory at the ankle joint following an injury, as well as the disruption of the surrounding musculature and the decreased range of motion (Hrysomallis, 2007). All of which could contribute to the athlete using a hip dominated strategy to maintain balance. Her center of gravity and weight symmetry shifted towards the injured ankle, which is unusual but just shows that weight bearing was not painful for her. This might be because the injury was minor, since she was able to finish practice following the injury. Strength symmetry shifted to the left leg which is consistent with her physical exam that showed decreased strength in the right ankle. The latency time increased in both legs, showing a slower reaction time to the platform shift. This might be correlated to the hip dominance because it would take longer for the hip musculature to respond than the ankle musculature. The adaptation showed a decrease during toes up but increased during the toes down condition, this could be due to the nature of the injury, that the posterior musculature remained intact while there was probably disruption to the anterior musculature. This is consistent with the literature that shows that edema in the joint decreases the planter flexion torque following an ankle sprain, and this finding showed that (Hopkins & Palmieri, 2004).
Return to Participation

As the athlete was cleared to return to participation her equilibrium had increased and for the majority had returned to baseline levels. Her strategy had increased as well and the majority of the scores were at baseline levels as well. Weight symmetry continued to shift to the right, which is a good sign showing that she is comfortable distributing her weight onto the affected leg. Compared to when she was injured the athlete’s adaptation was decreased in both conditions, showing that the subject used less force to adapt to rotational changes of the platform. However, strength symmetry continued to be left dominated, and compared to baseline her latency time was still increased. These two variables might indicate that the athlete was returned to participation slightly early, because these show that her strength was not equal and that the reaction time after the platform shift was slower than her baseline. Returning an athlete to participation too soon could be the reason that the athlete had a harder time throughout the season with re-injury. The athlete was able to be functional with all her strength testing, agility testing, and hop testing so it is difficult to determine based solely from a balance overview if she was returned to soon, because clinically she seemed capable to be functional and protect the joint (Guskiewicz & Perrin, 1996).

Two Weeks Post Return to Participation

Two weeks following the injury the subject’s equilibrium was returned to baseline or had increased, this was also shown in the strategy that was utilized. The subject was using more of an ankle dominated strategy than she was during her baseline testing. Her weight symmetry shifted to the left compared to when she was returned to participation,
that shift returned her to a more equally distribution between both legs. Strength also shifted to the right towards the injured leg, showing that the strength was moving towards equal, but the subject was still left dominated. Compared to baseline the subject’s latency was increased in the left leg, but had decreased in the right leg. This could be due to the rehabilitation that was being done on her right leg this probably increased her latency from her baseline in order to decrease the risk of re-injury. The adaptation was decreased in both conditions, showing that the athlete was able to respond with less force during rotational movements of the platform. This testing showed the athlete had improved over the past two weeks with the majority of the measurements improving or moving towards equal distribution. In some measurements the right leg had surpassed the left leg this is probably a method of compensating for the injured joint which helps in decreasing the chances of re-injury as the structures are continuing to heal (Gaerlan, 2010).

The subject’s results show that she might have returned to participation too early, because two weeks following her return to participation most of her measurements had returned to baseline or were improved. This subject struggled with re-injury the rest of the season so possibly if she had waited longer to return to participation than she might have responded better. It is impossible to know for sure but it could be one factor that played into her re-injuring the ankle throughout the season. This subject shows that it is important to take all factors into consideration when returning an athlete to participation, because it is impossible to know how the athlete will respond.

Comparing results from this subject and subject 4, both results immediately following the injuries, show a deficit during the Adaptation in the toes down condition but an increase during the toes up, this could be due to the posterior musculature
compensating for the injured tissue. This might be a finding that is specific to ankle injuries due to the tissue that is injured. Subject 4 had only one variable that was still significantly decreased, while subject 5 had many that were still significantly decreased. This difference in balance measurements between these two subjects might be one factor that was responsible for subject 5’s complications with the injury while subject 4 responded very well with no complications.

Case 6

Weight Bearing and Return to Participation

This subject obtained a left grade 2 ankle sprain during a game but she was able to finish the rest of the game (20’ left). She did not miss any playing time because the next day was a recovery day and then the following day was a game day and she was able to perform agility testing, hop testing and speed drills effectively so she was cleared to play in the game with tape and bracing. Immediately following the injury the athlete’s equilibrium had decreased or remained the same in three of the conditions and improved in the other three conditions. The strategy being utilized showed an increase in the majority of the conditions, so the athlete was able to use more of an ankle dominated strategy than during baseline testing. The center of gravity and the weight symmetry shifted so the athlete was placing more weight on the injured ankle. This was a good sign showing that the athlete felt comfortable placing the majority of her weight on the affected leg. The injured leg was lacking some strength though, which was not as evident on the physical exam. The latency showed that the injured leg was the same as baseline
results and the adaptation during both conditions had improved. The majority of these results are very positive following an injury which is probably why the athlete did not miss any playing time. This injury is different from the other two subject’s with grade 2 ankle sprains because it seems like she did not disrupt as much of the surrounding tissue as the other two. If she had additional injuries to the musculature she would have shown a decrease in strength on the physical exam, subsequently she would have disrupted the somatosensory receptors and her balance testing would have showed a deficit. This test however showed the majority of the results remained the same as the subject’s baseline measurements or improved, all of this information seems to be part of the reason she was able to continue playing on the injury (Hrysomallis, 2007).

Two Weeks Post Return to Participation

Two weeks following the injury the athlete had a decrease in equilibrium in three conditions, with the other three increasing or remaining the same. Compared to baseline results equilibrium overall increase or remained relatively the same. The strategy that was utilized remained the same through two conditions, increased during two conditions and decreased during two conditions. Compared to baseline results the strategy being utilized either remained the same or increased in the majority of the conditions. Weight symmetry shifted to the right away from the injury, but the strength symmetry shifted more to the left towards the injured leg. Regaining that equal strength is a very important aspect so the joint can protect itself using the muscles surrounding it. The latency improved in the left leg compared to baseline and to when the injury was obtained, this is consistent with the rehabilitation process that was used and focused attention on
regaining proprioception as well as strength, agility, and speed. The athlete also had an improvement in the adaptation, so that she was using less force to maintain the upright position during rotational movements.

This subject’s results following her injury for the majority were either improved or remained the same. The only result that was decreased was the strength symmetry, but that was not evident on the physical exam so the results might not have been significantly lower. These increased results were probably the reason that she was able to play through this injury and did not have to miss any games or practices. There was swelling present so there was definitely some tissue damage, but it was not as evident on her postural stability testing. This shows that swelling being present might not have as much of a negative effect as the muscular and surrounding tissue damage that might be present. It is hard to determine which affects the decrease in balance and postural stability but it is clear that it is affected by injury (Hrysomallis, 2007). This subject was able to compensate very well for the tissue that was damaged and was able to still be very functional and able to continue participating with this injury.

Case 7

Weight Bearing and Return to Participation

The subject obtained a right grade 1 groin strain, but was able to play and practice through this injury. The results showed that she had a decrease in equilibrium during the last three conditions, as well as a decrease in strategy utilized on the same conditions. The athlete had to use more of a hip dominated method to maintain postural stability than
her baseline testing which used more ankle dominated method to maintain postural
stability. This finding follows a natural response to a muscular injury that occurs below
the hip but above the ankle. Since there was a disruption of muscle fibers between the
two locations it seems fairly obvious that the strategy would shift to a more hip
dominated strategy (Guskiewicz & Perrin, 1996). Compared to her baseline testing her
center of gravity shifted to the right, but she was still placing more weight on her left leg
than on her right leg. This is a confusing measurement because during the athletes
baseline testing she was favoring her right leg by a significant amount, this could be due
to a previous injury that was not disclosed or some other reason that made her shift her
weight. It is difficult to determine, but it is still evident that following the injury she was
placing more weight on the unaffected leg than compared to the injured leg. The same
was also true with strength symmetry, it was stronger on the left leg at the time the
baseline testing was taken, and continued to be left dominated following the injury. This
finding is consistent with the slight decrease in strength on the physical exam. Latency
showed a decrease in both legs, showing that the athlete’s reaction time was not affected
very much by the injury. However, the adaptation showed an increase in both conditions,
this means that the athlete had to use a stronger force to maintain postural stability during
rotation of the platform. This finding could be due to the fact that the subject had a
muscular injury therefore the force of the other muscles were compensating for the
injured muscle (Gaerlan, 2010).
Two Weeks Post Return to Participation

Two weeks after the athlete had obtained the injury her equilibrium had increased during the final three conditions compared to when she was injured and the majority of the conditions had returned to baseline levels or higher. The strategy that was used increased or remained the same in the majority of the conditions compared to following the injury. Comparing the strategy used to the athlete’s baseline results showed that she was using more ankle dominance to maintain balance in the majority of the conditions. Compared to the baseline results the athlete’s weight symmetry and strength symmetry shifted to a more equal balance between the two legs. The athlete’s latency showed an increase in both legs, but a higher increase in the right leg compared to immediately following the injury, but compared to baseline the left leg had improved while the right leg was still slightly higher than the baseline results. Since the test immediately following the injury showed a decrease in latency but then after that the latency increased it is hard to determine the cause of that. Perhaps the athlete was experiencing some amount of fatigue on the second testing and this result showed that, it is impossible to determine since the athlete did not report and fatigue (Guskiewicz & Perrin, 1996).

Compared to her baseline results the latency improved in the uninjured leg, but showed a slower reaction time in the injured leg. The adaptation decreased in both conditions, showing the athlete used less force to maintain balance than following the injury and also had improved compared to baseline.

This athlete had a muscular injury so that could be the reason certain measurements were affected more than others. It is impossible to know if the athlete had other minor injuries that were not reported because some of her baseline results showed
favoring of her right leg. But specifically following the injury latency improved, showing she had a better reaction time when the platform was moved than her baseline results. This could be due to a learning curve from taking the test before, but it showed that this muscular injury did not disrupt that variable. However the adaptation measurements increased compared to the subject’s baseline results, showing that the subject required more force to maintain postural stability following a rotation shift of the platform, in both conditions. Adaptation then returned to baseline levels two weeks later, and had actually showed some improvement to baseline levels.

Overview

Comparing all of the subject’s results is difficult to show any consistency because all of the results vary based on the injury and the subject. Each testing should be looked at as a whole as well as the individual variable results, the more severe injuries either had multiple variables disrupted or had very significant decreases in one or two variables. Being aware of the variables that are initially disrupted following an injury and note the progression of those specific variables seems helpful as the athlete is getting closer to returning to participation. Taking each variable that is significantly decreased and attempting to determine, based on the anatomical structures that were disrupted, why they were disrupted gives the clinician a better overall view of the subject’s status. If someone has swelling in their knee it has been shown that the quadriceps (specifically the Vastus Medialis Oblique) is affected in a negative way (Hopkins, et. al., 2001). Therefore if a subject has a knee injury that results in swelling inside the joint, it should be anticipated
that variables like strength symmetry would be disrupted. The same concept is present with swelling inside the ankle joint, the force required during the toes down movement of the foot is decreased due to the swelling that is present (Hopkins & Palmieri, 2004). Therefore in an ankle injury where swelling is present the adaptation variables should be expected to be decreased, specifically in the toes down conditions. In each case there was an improvement in overall postural stability when returning to participation, either the number of variables that were below the baseline levels had decreased or the specific percentages had improved.

Conclusion

Each subject showed different responses to their injury and it was evident on the differences between their scores. Immediately following an injury it would seem that the measurements would be decreased or affected negatively due to the tissue damage that occurred. However, this was not the case in all of the subjects; some variables even showed an improvement following injury. This is the reason that each injury should be looked at individually, treated appropriately and return to play decisions should be made based on all of the information available. Certain individuals might be able to compensate for the lack of postural stability better than others, so it makes objectively measuring balance and postural stability that much more crucial. This seemed evident in two ways, either the subject was able to compensate well enough that they did not miss much playing time or none at all, or it seemed that subjects who had previous injuries were also able to compensate much better than a first time injury.
There are many different variables that should be considered when trying to
determine when an athlete should be cleared for participation. Balance is simply one area
that should be taken into consideration when making this decision. Using technology like
the Neurocom balance system it is easier to determine exactly how much balance and
postural stability is disrupted following an injury and can show the progression that the
athlete makes throughout the rehabilitation process. Obviously some variables should be
given more consideration when reviewing a subject’s results than others. It seemed that
subjects who had significant weight symmetry shifts also had an increase in pain,
specifically with walking and weight bearing activities. Variables like strategy used,
weight symmetry, and strength symmetry seemed to be affected in the majority of the
subjects immediately following the injury, and therefore those variables should be
weighted slightly more than others since they seem to be affected more consistently
during all injuries. All the variables measured should be looked at in a practical manner
to determine why they might be affected, in order to gain a better overall assessment of
the athlete.

The variables that are measured during the balance testing should all be looked at
individually to determine if they have increased, decreased or have stayed relatively the
same. However, we cannot forget that all the individual scores make up a small part of
the bigger picture. There are many variables that can cause balance scores to fluctuate
that are out of the control of the tester, this should be taken into consideration for every
test. Variables such as fatigue, concentration, sickness, other minor injuries that were not
reported, as well as the learning curve that result from multiple testing. If one of the
variables tested show a slight decrease but all the rest have improved significantly it
should be taken into consideration that the overall postural stability has been improved.

The nature of the injury should also be considered and specifically the exact types
of tissue and location of the tissue that has been injured. This can affect certain variables
during testing and not others, therefore the ones affected should be looked at more
closely. As the athlete progresses through the rehabilitation process it is easier to set
goals for the athlete when they have an objective measure of exactly where they are and
where they need to be before they return to participation. Using this technology should
be something that can be utilized for everyday usage; it provides very useful information
when attempting to objectively determine an athlete's balance and postural stability.


MEMORANDUM

TO: Dennis Dolny
    Adam Raikes

FROM: Richard D. Gordin, Acting IRB Chair
       True M. Fox, IRB Administrator

SUBJECT: USU Student-Athlete Screening for Dynamic Postural Balance, Stability and Dynamic Vision

Your proposal has been reviewed by the Institutional Review Board and is approved under expedite procedure #4.

There is no more than minimal risk to the subjects.
There is greater than minimal risk to the subjects.

This approval applies only to the proposal currently on file for the period of one year. If your study extends beyond this approval period, you must contact this office to request an annual review of this research. Any change affecting human subjects must be approved by the Board prior to implementation. Injuries or any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Institutional Review Board.

Prior to involving human subjects, properly executed informed consent must be obtained from each subject or from an authorized representative, and documentation of informed consent must be kept on file for at least three years after the project ends. Each subject must be furnished with a copy of the informed consent document for their personal records.

The research activities listed below are expedited from IRB review based on the Department of Health and Human Services (DHHS) regulations for the protection of human research subjects, 45 CFR Part 46, as amended to include provisions of the Federal Policy for the Protection of Human Subjects, November 9, 1998.

Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. Examples: (a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject’s privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography, (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.
MEMORANDUM

TO: Dennis Dolny
    Adam Raikes

FROM: Richard D. Gordin, Acting IRB Chair
       True M. Rubal, IRB Administrator

SUBJECT: USU Student-Athlete Screening for Dynamic Postural Balance, Stability and Dynamic Vision

Approval Category: Exempt # Expedite #4

This approval applies only to the proposal currently on file. Any change affecting participants must be approved by the IRB prior to implementation. The Institutional Review Board originally approved your protocol on 3/21/2011. As required for yearly continuation review, you have received another year’s approval up to the day prior to the anniversary date. All approved Exempt protocols are subject to continuing review on a random basis annually, which may include the examination of records connected with the project. Injuries or any unanticipated problems involving risk to subjects or to others must be reported immediately to the IRB Office (797-1821).

Prior to involving participants (if applicable), properly executed informed consent must be obtained from each participant or from an authorized representative, and documentation of informed consent must be kept on file for at least three years after the project ends. Each participant must be furnished with a copy of the informed consent document for their personal records.

Please note that the data cannot be used for another study or an extension of the current study without IRB approval either through modification (addendum) or a new application.
APPENDIX B

INFORMED CONSENT

USU Student-Athlete Screening for Dynamic Postural Balance, Stability and Dynamic Vision

Introduction/Purpose: Professor Dennis Dolny and graduate student Adam Raikes in the Department of HPER at Utah State University are conducting a research study to find out more about Postural Stability and Balance in Student-Athletes. You have been asked to take part because you are a student-athlete. There will be approximately 350 total participants in this research.

Procedures: If you agree to be in this research study, you will be screened for measures of postural balance and dynamic vision. This requires you to: I.) On the Balance System platform, stand perfectly still for 18-20 second time periods for a total standing time of approximately 6-8 minutes. During these brief time periods you will be asked to: a) close your eyes for six of those periods; b) stand still while the floor you stand on slowly tilts forward or back very slightly while you maintain a standing position. II.) While standing upright the platform will shift either forward (3 separate times) or backwards (3 separate times) a few centimeters while you remain standing in place. III.) While standing upright the platform will tilt (toes down) either forward (3 separate times) or toli (toes up) backwards (3 separate times) a few centimeters while you remain standing in place. IV.) While seated your dynamic vision will be evaluated. You will be asked to move your head from side-to-side (about ½ way from looking straight ahead to your shoulder position) while you focus on a computer screen in front of you. You will be asked to read a letter “E” that will be briefly displayed on the screen. You will be asked to complete approximately 30 recognitions of the letter E during this portion of testing.

New Findings: During the course of this research study, you will be informed of any significant new findings (either good or bad), such as changes in the risks or benefits resulting from participation in the research, or new alternatives to participation that might cause you to change your mind about continuing in the study. If new information is obtained that is relevant or useful to you, or if the procedures and/or methods change at any time throughout this study, your consent to continue participating in this study will be obtained again.

Risks: Participation in this research study may involve some added risks or discomforts. These include mild fatigue due to standing or slight nausea from the head turning test. You will be secured in place with a vest-like harness during all standing tests. If any problematic event occurs during testing, all procedures will be terminated and you will be referred to the USU Sports Medicine staff for consultation. In the event of a subsequent head injury due to sports participation, only the USU Director of Athletic Training, USU Team Physicians and Sports Medicine staff will review the results of these tests which will serve as a baseline measure.

Benefits: There may or may not be any direct benefit to you from these procedures. The investigator, however, may learn more about your individual postural balance and stability characteristics. This information may inform you relative to developing strategies to enhance your personal dynamic balance and/or postural stability. This research may also allow us to determine normative data for dynamic postural balance and stability relative to a student-athlete population.

Explanation & offer to answer questions: Dr. Dennis Dolny or Adam Raikes has explained this research study to you and answered your questions. If you have other questions or research-related problems, you may reach Professor Dolny at (435) 797-7579.
INFORMED CONSENT
USU Student-Athlete Screening for Dynamic Postural Balance, Stability and Dynamic Vision
INFORMED CONSENT

USU Student-Athlete Screening for Dynamic Postural Balance, Stability and Dynamic Vision

Voluntary nature of participation and right to withdraw without consequence

Participation in research is entirely voluntary. You may refuse to participate or withdraw at any time without consequence or loss of benefits. Data from these evaluations will not be used for future evaluations. You may be withdrawn from this study without your consent by the investigator if there is an unanticipated injury or problem.

Confidentiality Research records will be kept confidential, consistent with federal and state regulations. Only the investigator and Student Researcher will have access to the data which will be kept in a locked computer file in a locked room. To protect your privacy, your name will be replaced with a code on all data collected. This coding system will be kept separate from the data in a locked computer in a locked office. Personal, identifiable information will be kept for the time while you are enrolled at USU. No athletic coaches will be provided results of these evaluations. This code will be destroyed once you are no longer participating with Aggie athletics, graduate or transfer.

IRB Approval Statement The Institutional Review Board for the protection of human participants at USU has approved this research study. If you have any pertinent questions or concerns about your rights or a research-related injury, you may contact the IRB Administrator at (435) 797-0567 or email irb@usu.edu. If you have a concern or complaint about the research and you would like to contact someone other than the research team, you may contact the IRB Administrator to obtain information or to offer input.

Copy of consent You have been given two copies of this Informed Consent. Please sign both copies and retain one copy for your files.

Investigator Statement “I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered.”

Dennis Dolny, Principal Investigator (435-797-7579) (dennis.dolny@usu.edu)

Adam Raikes, Student Researcher (435-797-3636) (Adam.Raikes@aggiemail.usu.edu)

Signature of Participant By signing below, I agree to participate.

Participant’s signature

Date
INFORMED CONSENT
USU Student-Athlete Screening for Dynamic Postural Balance, Stability and Dynamic Vision

Name

Date
Menisectomy/Chondroplasty Rehabilitation

**Precautions & Progression**

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**Strengthening & Conditioning**

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<th>Phase III: 4+ Weeks</th>
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Ankle Grade II Sprain Rehabilitation Program

The GLSM Ankle Grade II Sprain Rehabilitation Program is an evidence-based and soft tissue healing dependent program which allows patients to progress to vocational and sports-related activities as quickly and safely as possible. Individual variations will occur depending on patient tolerance and response to treatment. Patients usually progress to full activities in 3-4 weeks. For grade I sprains, accelerate program by 1-2 weeks with return to activities expected within 1 week. For grade III, the program can be decelerated 1-2 weeks with return to activities around 4-6 weeks. Please contact us at 1-800-962-9567 ext. 56600 if you have questions or concerns.

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<td><strong>ROM:</strong> Full with no limitations</td>
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</tr>
<tr>
<td><strong>Brace:</strong> Possible use of Jones splint or active ankle. Ace wrap with felt horse shoe pad</td>
<td><strong>Brace:</strong> Active ankle brace</td>
<td><strong>Brace:</strong> Active ankle or lace-up brace</td>
</tr>
<tr>
<td><strong>Modalities:</strong> Cryotherapy Pulsed US for 3-5 days Continuous US after 3-5 days IFC for pain and/or swelling</td>
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</tr>
<tr>
<td><strong>RX:</strong> Recommendations: Emphasis on protection, rest, ice, compression, and elevation</td>
<td><strong>RX:</strong> Recommendations: Progress per patient tolerance Bike with resistance 2 wks Elliptical Runner, Stairmaster</td>
<td><strong>RX:</strong> Recommendations: Progress per patient tolerance Bike with resistance Elliptical Runner / Stairmaster Running program if 75% strength</td>
</tr>
<tr>
<td>PROM / AAROM / AROM per tolerance</td>
<td>PROM / AAROM / AROM Flexibility exercises gastrosoleus- slant board Isotonic DF / PF Isokinetic DF/ PF VSRP 60-120 deg per second Isotonic INV / EV Isokinetic INV/EV progress to VSRP 60-180 deg per second Total leg strengthening Hip 4 way SLR Hamstring isotonics Quadriceps isotonics Isokinetic quadriceps/hamstrings CKC exercises – leg press, step-ups, squats, FW and lateral partial lunges progress to full lunges at 2 wks 2 wks Lateral movements – shuffles, eurolide Sub-max impact activities Balance / Proprioception Perturbation training Core stability / CV conditioning</td>
<td><strong>Flexibility exercises:</strong> Isotonic or Isokinetic DF/ PF Isotonic or Isokinetic INV/EV Total Leg Strengthening Hip strengthening CKC exercises Balance / Proprioception Perturbation training Plyometrics / Agility exercises / Sport-specific exercises if 75% strength Core stability / CV conditioning</td>
</tr>
<tr>
<td><strong>Balance / Proprioception exercises partial WB avoiding Inversion if inversion sprain</strong></td>
<td><strong>Isokinetic quadriceps/hamstrings</strong> CKC exercises – leg press, step-ups, squats, FW and lateral partial lunges progress to full lunges at 2 wks 2 wks Lateral movements – shuffles, eurolide Sub-max impact activities</td>
<td><strong>Testing:</strong> 3 wks Biodex Test FXN Test when appropriate</td>
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<tr>
<td><strong>CV conditioning</strong></td>
<td><strong>Core stability / CV conditioning</strong></td>
<td><strong>Return to Work/Sport</strong> No pain or effusion Full ROM Isokinetic Strength- 90% Functional Tests – 90% MD approval Brace for athletic activities</td>
</tr>
<tr>
<td><strong>Upper body exercises</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Updated 12/03*
Phase I (1 – 5 days post-injury)
- Modalities
  - Prn for pain and swelling (ice, IFC)
  - Consider contrast bath if significant edema
- ROM
  - PROM and stretches
  - AROM in pain-free range
  - Joint mobs to talocrural, subtalar, intermetatarsal and MTP jts.
- Strengthening
  - Isometrics
  - Knee/hip strengthening (open-chain if WB restricted or not tolerated)
- Gait
  - WB as directed by physician
  - Begin wt shifting if WB allowed
- Boot/brace wear: as directed by physician

Phase II (5 days – 4 weeks post-injury)
- Modalities: continue prn
- ROM: continue as phase I
- Strengthening/Balance
  - Light manual resistive exercises
  - Progress to Theraband as tolerated
  - Knee/hip strengthening, progressing to closed-chain as tolerated (as weight bearing allows)
- Gait
  - WB as directed by physician
  - Continue wt shifting, progressing as tolerated
- Boot/brace wear: as directed by physician

Phase III (4 – 10 weeks post-injury)
- Modalities: continue as needed
- ROM: continue as phase II but more aggressive
- Strengthening/Balance
  - BAPS
  - Balance board
  - Progress from double to single leg balance activities
  - Progress with closed-chain strengthening
- Gait: WBAT
- Boot/Brace: D/C'd
Phase IV (10+ weeks post-injury)
- Advance to running and agility drills, plyometrics, sports-specific activities as tolerated
- Functional Testing: less than 25% deficit for non-athletes, less than 20% for athletes

Adapted from:
1) Brotzman SB, Wilk KE. Clinical Orthopedic Rehabilitation. 2nd Ed. Philadelphia: Mosby; 2003
Groin Strain Rehabilitation

Phase I
A. Ice massage with hip abducted and externally rotated as far as possible. Perform before and after exercise and as often as possible between exercise sessions.
B. Mild hip spica compression wrap for initial 48 - 72 hours.
C. Non-steroidal anti-inflammatory (NSAID) medication as prescribed by physician.
D. Mild muscle relaxant medication as prescribed by physician.
E. Static groin stretching exercises as tolerated 4 - 5 times daily. Each stretch should be held for 15 - 30 seconds. DO NOT BOUNCE.
F. Stationary Bicycle riding with seat as low as possible at a low to moderate intensity.

Supine Groin Stretch: While lying on back with knees bend and soles of feet together, relax and allow gravity to stretch groin area.

Sitting Groin Stretch: Sitting on floor, put soles of feet together with hand and pull heels towards body. Gently pull upper body forward until a stretch is felt in the groin area. You may also push down on the knees with elbows to intensify stretch.

Wall Stretch: Start with legs elevated and close together against a wall. Slowly separate legs with heels in contact with the wall until an easy stretch is felt. Slowly squeeze legs together . Repeat.

Sit and Reach: Sit on floor with legs straight and spread shoulder width apart or greater. With a flat back reach across body with leg hand to right foot to feel a comfortable stretch. Alternate and repeat to left side.

Lunge Stretch: Kneel on left knee with foot turned to inside. The right knee should be bent to 90° angle. Put hand on floor to inside of upper body. Move hips downward to stretch inside of right groin. Alternate and repeat.
Advanced Groin Stretch: Place one leg on edge of a table with opposite leg spread as far as possible and on ground. Slowly lean upper body to side of the leg on the ground. Hold and repeat to other side.

Quad Stretch: While standing, grasp top of right foot with left hand and gently pull heel with left hand toward buttocks. Hold and repeat with other leg.

PNF (Facilitated stretching): A partner will help by gently pressing the knees outward. Be careful not to overstretch.

PHASE II

A. Begin moist heat application before exercise after danger of internal bleeding has passed (2 - 4 days).
B. Begin physician prescribed ultrasound with or without electrical muscle stimulation before exercise when danger of internal bleeding has passed.
C. Continue NSAIDs and muscle relaxants as prescribed by a physician.
D. Continue stretching.
E. Begin Groin Strengthening Exercises:

1) Straight Leg Raises:
   a) Adduction
   b) Abduction
   c) Supine
   d) Prone

2) Hip Flexion:
   Sit on edge of table with feet resting on floor. Lift involved leg towards chest. Hold and slowly lower to beginning position. Repeat 30 times, increasing repetitions as strength improves.

3) Hip Internal/External Rotation:
   Sit on edge of firm surface with feet suspended above floor. Rotate thigh about the axis of the hip, turning lower leg slowly inside as far as possible then turn to outside slowly. Repeat 30 times, increasing repetitions as strength improves.
4) Ball Squeeze:
Sit on edge of chair, place 8" - 10" ball between knees. Slowly contract groin muscles,
squeezing ball as tightly as possible and hold for 5 - 10 seconds. Relax and repeat 30
times.

5) Slide Board:

6) Front Step-Ups:
Stand directly behind a 4" - 6" box or step. Step up on box with involved leg
followed by uninvolved leg. Step down with involved leg followed by uninvolved
leg. Repeat. Progress by increasing repetitions then step height.

F. Begin interval work on stationary bicycle.
G. Begin light jogging on smooth, straight surface.
H. Begin stair climbing exercises, increasing step height as tolerated.
I. Ice massage after exercises.
J. Progress to Phase III when Phase II can be completed with little or no discomfort.

Note: During all exertional activities a hip spica compression wrap should be worn.

Progression for weighted activities (# 1 - 3 above)

3 x 10
Day off
3 x 15
Day off
3 x 20
Day off

Add 1 - 2#

Phase III

A. Continue all activities from Phase II
B. Progress strengthening exercises as tolerated.
C. Begin functional activities to tolerance:
   1) Canoeing,
   2) High Knee Running,
   3) Backward Running,
   4) Bounding Drills,
   5) Vertical leaps progressing to horizontal jumping, and
   6) Sprinting with running starts and coast-through stops.
D. Return to full activities as tolerated when Phase III can be completed with little or no discomfort
and bilateral groin strength is equal.
The GLSM MCL Grade II Sprain 2+ Instability (Unstable) Rehabilitation Program is an evidence-based and soft tissue healing dependent program that allows patients to progress to vocational and sports-related activities as quickly and safely as possible. Individual variations will occur depending on patient tolerance and response to treatment. Femoral tears may move along quicker with ROM based on end feel to valgus stress testing as there is a higher tendency for joint stiffness. Patients usually return to full activities in 6-8 wks. Please contact us at 1-800-362-9567 ext. 58600 if you have questions or concerns.

<table>
<thead>
<tr>
<th>Phase I: 0-3 weeks</th>
<th>Phase II: 3-6 weeks</th>
<th>Phase III: 6 weeks</th>
</tr>
</thead>
</table>
| **ROM:** Drop lock brace  
wk 0-2: 30-90  
wk 2-3: 20-110  
wk 3-4: 10-110  
Progression may be modified based on end feel and knee alignment. |
| **ROM:** Drop lock brace  
wk 3-4: 10-110  
wk 4-5: 0-120  
wk 5-6: Full ROM, Switch to double upright brace with 10 degree extension stop |
| **ROM:** Double upright brace  
Full ROM |
| **WB:** wk 0-1: NWB  
wk 1-2: 25%  
wk 2-3: 50%-75% |
| **WB:** wk 3-4: 100% with crutches  
wk 4: Full crutches if good quad control / normal gait pattern |
| **WB:** Full with no limitations |
| **Modalities:** Cryotherapy  
Pulsed US  
IFC for pain/effusion  
NMES quadriceps |
| **Modalities:** Cryotherapy  
Pulsed US  
IFC for pain/effusion  
NMES quadriceps |
| **Modalities:** Cryotherapy |
| **RX:** Recommendations:  
PROM / AAROM / AROM to tolerance per ROM guidelines. Encourage ROM to facilitate scar remodeling and allow MCL healing  
Bike light resistance  
Cross friction massage  
Flexibility exercises  
Biofeedback QS, SLR, CKC knee extension per ROM  
M-1 Quads/Hams 10, 30, 50, 70, 90 deg  
Hamstrings isotonic per ROM  
Quadriceps isotonic per ROM  
Total leg strengthening  
Hip 4 way SLR (proximal pad placement for Hip Adduction)  
CKC exercises - leg press, step-ups, FW lunges, squats, heel raises  
Balance / Proprioception  
Perturbation training  
CV conditioning  
Core stability training  
Upper body exercises |
| **RX:** Recommendations:  
PROM / AAROM / AROM  
Bike with resistance  
Elliptical Runner / Stairmaster  
Cross friction massage  
Flexibility exercise  
Biofeedback SLR, CKC knee extension  
Hamstring isotonics  
Quadriceps isotonics  
Isokinetic quadriceps/hamstrings  
Hip 4 way SLR (proximal pad placement for Hip Adduction)  
Heel raises  
CKC exercises - leg press, step-ups, FW and lateral lunges, squats  
Total leg strengthening  
Functional strengthening  
Core stability training  
Balance / Proprioception  
Perturbation training  
Lateral movements - sidestrokes, euroglide  
3 wks Return to running if 75% strength  
4 wks Plyometrics / Agility and Sport-specific exercises if 75% strength |
| **RX:**  
Bike with resistance  
Elliptical Runner / Stairmaster  
Running program if 75% strength  
Flexibility exercises  
Isokinetic quadriceps/hamstrings  
Isokinetic quadriceps/hamstrings  
Hip strengthening  
CKC exercises  
Total leg strengthening  
Functional strengthening  
Balance / Proprioception  
Perturbation training  
Core stability training  
Plyometrics / Agility and  
Sport-specific exercises if 75% strength |
| **Testing:**  
3-4 wks Linea / Biodex Test  
FXN Test when appropriate |
| **Return to Work/Sport**  
No pain or effusion  
Full ROM  
Isokinetic strength - 90%  
Functional Tests – 90%  
MD approval  
Brace for athletic activities |

Updated 2/2007