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# Effects of Active Video Games in the Rehabilitation of Ankle Sprains and Chronic Ankle Instability

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EFFECTS OF ACTIVE VIDEO GAMES IN THE REHABILITATION  
OF ANKLE SPRAINS AND CHRONIC ANKLE INSTABILITY

by

Nate Maresh

A Thesis Submitted in

Partial Fulfillment of the

Requirements for the Degree of

Master of Science

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at

The University of Wisconsin – Milwaukee

August 2014

## ABSTRACT

# EFFECTS OF ACTIVE VIDEO GAMES IN THE REHABILITATION OF ACUTE ANKLE SPRAINS AND CHRONIC ANKLE INSTABILITY

by

Nathan Maresh

The University of Wisconsin-Milwaukee, 2014  
Under the Supervision of Professor Jennifer Earl-Boehm

INTRODUCTION: Research into the treatment of acute lateral ankle sprains with individuals currently suffering from an acute injury, rather than a history of injury, is sparse. These acute injuries have psychological effects (e.g. confidence in one's readiness to return to play, changes to one's mood, adherence to the rehabilitation) to the individual that must be recognized as they have the potential to affect the rehabilitation process as much as the physical effects. In spite of previous research into the treatment of acute lateral ankle sprains the rate of recurrent injury remains high. With these recurrent ankle sprains comes the development of chronic ankle instability. Chronic ankle instability has mechanical and perceived components which factor into the extent of the condition. Individuals with long term chronic ankle instability may suffer from continued pain as well as decreased participation in physical activity and are at risk to develop early onset ankle osteoarthritis. The implementation of active video gaming within the rehabilitation environment has become popular in spite of the lack of empirical studies evaluating its effectiveness. Few studies have evaluated the use of active video gaming in a musculoskeletal context, with even fewer evaluating both the

physical and psychological effects of such a modality. **PURPOSE:** The primary purpose of this study was to describe the functional, select psychosocial and patient-oriented outcomes of a rehabilitation program including active video gaming and a traditional rehabilitation protocol in the treatment of patients with acute lateral ankle sprains. The secondary purpose of this study was to compare and describe the functional, psychosocial, and patient-oriented outcomes of a rehabilitation program including active video gaming and a traditional rehabilitation protocol in the treatment of patients with chronic ankle instability. **METHODS:** Two collegiate student-athletes with acute lateral ankle sprains and 20 individuals with chronic ankle instability were recruited for the current study. Participants were randomly assigned to a traditional treatment protocol or a treatment protocol using active video games with the Xbox Kinect™ during the balance training portion of their rehabilitation. Participants' static and dynamic stability, confidence in their readiness to return to play, mood states, adherence to the rehabilitation, and self-reported ankle function were recorded at multiple points during the rehabilitation. **RESULTS:** The acute active video gaming participant showed consistently better mood states during the balance training protocol than did the traditional participant while both showed similar improvements in balance. In the chronic condition similar improvements were seen in balance ability, confidence in their readiness to return to play, adherence to the rehabilitation, and self-reported ankle function. **CONCLUSIONS:** The use of active video gaming in the rehabilitation of acute lateral ankle sprains appears to have a positive effect on mood while having similar effects on balance compared to the traditional protocol. This positive effect on mood has potential benefits for one's performance in the rehabilitation but also in their confidence to return to participation in physical activity and decrease the chance for re-injury. In the rehabilitation of chronic ankle instability the comparable improvements in balance, confidence in their readiness to return to play, and self-reported ankle function provide

evidence that implementing active video gaming into a rehabilitation protocol does not have any adverse effects. The improvements seen by both groups in their confidence to return to play may have potential to be a key component to a successful rehabilitation outcome in the treatment of chronic ankle instability in which perception may play a large role.

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## Chapter I: Introduction

### *Background of the problem*

Participation in physical activity is a common pastime for many individuals for recreation, health benefits, enjoyment and even competition (Fong, Hong, Lap-Ki, Yung, & Kai-Ming, 2007). With this participation in physical activity come the risks of sustaining a physical injury. Injuries sustained in sport and exercise comprise 18-33% of emergency room visits (Finch, Valuri, & Ozanne-Smith, 1998; Uitenbroek, 1996). Likewise, since the late 1980's the rate of participation in collegiate athletics has increased by 80% for female athletes and 20% for males (Hootman, Dick, & Agel, 2007). With this rise in participation rates comes an increase in the instances in which athletes are at risk for sustaining an injury (Agel, Palmieri-Smith, Dick, Wojtys, & Marshall, 2007). While the number of athletes now participating in athletics continues to increase and the overall injury rate in college athletics has remained stable, the total number of injury occurrences also increases, particularly in the case of lateral ankle sprains (Hootman et al., 2007).

Lateral ankle sprains (here on out referred to as ankle sprains) are one of the most common injuries suffered in sports and exercise participation (Agel et al., 2007; Aoki, O'Hata, Kohno, Morikawa, & Seki, 2012; Fong et al., 2007). This injury occurs most often in activities that involve quick changes of direction and landing activities (McGuine, Brooks, & Hetzel, 2011; McKay, Goldie, Payne, & Oakes, 2001; Zöch, Fialka-Moser, & Quittan, 2003). While the anatomy of the ankle provides excellent stability when it is in a neutral position, it provides poor stability during these change of direction and landing activities increasing the risk of suffering a lateral ankle sprain (Renström & Konradsen, 1997).

There are different types risk factors that can lead to ankle sprains; extrinsic and intrinsic (Fousekis, Tsepis, & Vagenas, 2012). Extrinsic factors, such as a direct blow to the ankle or landing on an opponent's foot, are unavoidable risks of sports participation. The intrinsic factors, such as proprioception deficits, mechanical laxity, or a previous history of ankle sprains, contribute to non-contact ankle sprains (Collado et al., 2010; Fousekis et al., 2012; Hertel, 2002; Hiller, Kilbreath, & Refshauge, 2011). During moments of landing and cutting the musculature of the ankle and lower leg must assist the ligaments to limit the amount of motion of the ankle joint. In the instance of ankle sprains, which are sustained during excessive inversion and plantarflexion, the evertors of the lower leg are often recruited to slow or stop the progression of ankle inversion (Hertel, 2002; Renström & Konradsen, 1997). As the ankle moves into inversion, mechanoreceptors in the lateral ankle ligaments sense this joint position deviation and the ankle evertors are activated to attempt to return the ankle to a neutral position to avoid injury of ligaments (Michelson & Hutchins, 1995). If these mechanoreceptors have been damaged by previous injury, the ability to accurately judge the position of a joint may compromise the body's ability to protect the ankle from subsequent injury. The ability of the body to sense a joint's position in space, or proprioception, is essential for quick reflexive postural corrections at the ankle (Hertel, 2002). Proprioception deficits have been shown to be present following acute ankle sprains through damage to the sensory mechanoreceptors in the ankle (Michelson & Hutchins, 1995). Following an ankle sprain, especially in recurrent sprains, it is important to reestablish these deficits to ensure a full recovery and decrease the chance of re-injury. However, the extent to which these factors may predispose an individual to suffer an ankle sprain is still conflicting (Collado et al., 2010; Fousekis et al., 2012; Hertel, 2002; Hiller et al., 2011).

In addition to physical risk factors leading to injury, various psychological factors may also predispose an individual to an injury. Increased levels of stress can have negative effects when entering a stressful athletic situation (Williams & Andersen, 1998). These effects may manifest as a poor appraisal of the stressful athletic event or may cause a decrease in situational awareness as well as increased body tension. These negative effects ultimately increase the chance of sustaining an injury (Williams & Andersen, 1998).

In the event of an ankle sprain, regardless of the predisposing risk factors, individuals typically experience varied levels of pain, swelling, and a loss of function depending on the severity of the injury. Many individuals also experience a number of psychosocial reactions to the injury and subsequent rehabilitation process, such as anger, depression or fatigue, which also impacts the rehabilitation process (Arvinen-Barrow, Hemmings, Weigand, Becker, & Booth, 2007). Acute care for the injury typically includes the protocol of protection, rest, ice, compression, and elevation (PRICE) to control pain and swelling and restore normal function as soon as possible (Matharu, Najran, & Porter, 2010; Renström & Konradsen, 1997). Timely pain reduction and restoration of normal function help the individual develop a positive cognitive appraisal of the injury and help individuals cope with their injury (Kamphoff, Thomae, & Hamson-Utley, 2013). Strength training is incorporated to address weaknesses that occurred as a result of the injury (Chinn & Hertel, 2010; Collado et al., 2010; Han & Ricard, 2011). To address proprioceptive and postural control deficits balance exercises are essential to the rehabilitation of ankle sprains (Bassett & Prapavessis, 2007; Emery & Meeuwisse, 2010). Research shows a reduction in recurrent ankle sprains immediately following balance training (Bleakley et al., 2010; McKeon & Hertel, 2008; van der Wees et al., 2006) but long term follow-ups have not been utilized to evaluate effectiveness following completion of a balance training program. However, the level of adherence to these rehabilitation protocols is often a determinant to

successful rehabilitation outcomes (Arvinen-Barrow et al., 2007). Adding variety during this stage of the rehabilitation helps to improve that adherence as well as helps the individuals cope with their injury (Arvinen-Barrow et al., 2007; Kamphoff et al., 2013).

Psychosocial frameworks exist that help explain an individual's response to the rehabilitation process, their performance in the rehabilitation, and their possible outcomes following the rehabilitation. The biopsychosocial model of sports injury rehabilitation (Brewer, Andersen, & Van Raalte, 2002) suggests that biological, psychological, and social factors can impact each other as well as the outcome of a rehabilitation program. Characteristics of the injury (e.g. severity or previous history of injury), sociodemographic factors (e.g. age or gender), biological factors (e.g. tissue repair or nutrition), social and contextual factors (e.g. life stress or the rehabilitation environment) and rehabilitation outcomes (e.g. changes in pain levels or treatment satisfaction) all have the ability to affect the individual's cognitive appraisal, emotional and behavioral responses. Conversely, these psychological factors also have the ability to affect the biological factors and rehabilitation outcomes, excluding static factors of injury characteristics and sociodemographic factors (Brewer et al., 2002).

Understanding how these different factors can influence each other helps us understand how the rehabilitation process can be improved. By manipulating social and contextual factors we may be able to positively influence how the injured patient thinks, feels and behaves during the rehabilitation. A rehabilitation environment that adds more variety to the rehabilitation protocol has been shown to have an effect on how successfully individuals cope with their injury (Arvinen-Barrow et al., 2007; Clement, Granquist, & Arvinen-Barrow, 2013; Clement et al., 2012). In the treatment of ankle sprains and CAI, variety can be introduced



through utilizing different types of surfaces or adding a secondary task such as playing catch during the balance training protocol.

A novel method of adding variety into the rehabilitation environment has been introducing active video game (AVG) systems to the rehabilitation protocol. The majority of this research has been with elderly populations in balance training and stroke recovery (C. S. Bell et al., 2011; Celinder & Peoples, 2012; Hsu et al., 2011). Some studies propose increases in motivation (Almari, Kim, Cha, & El Saddik, 2010; Celinder & Peoples, 2012; Fitzgerald, Trakarnratanakul, Smyth, & Caulfield, 2010; Pasch, Bianchi-Berthouze, van Dijk, & Nijholt, 2009) and adherence (Meldrum et al., 2012; Middlemas, Basilicato, Prybicien, Savoia, & Biodoglio, 2009) as a result of the addition of the AVG . Results from these studies have shown comparable functional outcomes while psychological outcomes are either no different or significantly better when compared with traditional therapies (Baltaci, Harput, Haksever, Ulusoy, & Ozer, 2012; C. S. Bell et al., 2011; Celinder & Peoples, 2012; Fitzgerald et al., 2010). Anecdotal evidence also suggests that introducing current AVG platforms into the rehabilitation setting may increase patients' enjoyment and motivation towards their prescribed rehabilitation (Coyne, 2008; Mickey, 2012). To date there has been limited research on the effects of AVG in in the rehabilitation of musculoskeletal injuries (Baltaci et al., 2012; Fung, Ho, Shaffer, Chung, & Gomez, 2012; Sims, Cosby, Saliba, Hertel, & Saliba, 2013). These studies have shown minimal differences in functional outcomes when compared to traditional therapy but have not evaluated psychological traits affected by their interventions. Currently only one study has looked at the effects of AVG in participants with a history of ankle sprains but did not define if these individuals suffered from CAI (Vernadakis, Derri, Tsitskari, & Antoniou, 2014). The effects of AVG have also not been looked at in the rehabilitation of acute ankle sprains. Likewise, the

Xbox Kinect gaming system has only been utilized in one musculoskeletal rehabilitation study (Vernadakis et al., 2014).

Although recovery from an acute ankle sprain can be relatively quick, many people report having long term effects from their ankle sprain. These problems include symptoms of pain, weakness, or feelings of instability resulting in repeated ankle sprains. This condition is known as chronic ankle instability (CAI). CAI is comprised of two main characteristics; mechanical and functional, or perceived, instability. Mechanical instability manifests as ligamentous laxity while functional instability is subjective in nature with reports of weakness and “giving out” of the ankle. CAI commonly leads to repeated ankle sprains which can decrease one’s quality of life and preventing up to 72% of people from returning to their previous level of activity (Hiller et al., 2011). Rehabilitation for CAI is often the same as that of acute ankle sprains but with varying levels of evidence and a lack of a consensus in the treatment of ankle sprains and CAI an investigation into an approach integrating treatment of both physical and psychological symptoms of the injury or condition.

The addition of AVG to a rehabilitation protocol may have the ability to provide improvements in balance and self-reported ankle function comparable to traditional exercises while at the same time having positive effects on one’s confidence to return to play, mood states, and adherence to the rehabilitation program. These positive effects on confidence, mood, and adherence not only can improve performance within the rehabilitation setting but also improve the outcome of the injury rehabilitation as well as reducing the chance of re-injury in the future.

## *Purpose*

The primary purpose of this study was to describe the functional, select psychosocial and patient-oriented outcomes of a rehabilitation program including AVG and a traditional rehabilitation protocol in the treatment of patients with acute lateral ankle sprains. The secondary purpose of this study was to compare and describe the functional, psychosocial, and patient-oriented outcomes of a rehabilitation program including AVG and a traditional rehabilitation protocol in the treatment of patients with CAI. To achieve this purpose, the following aims were investigated:

- 1) To compare the changes in static and dynamic balance between AVG and traditional rehabilitation protocols,
- 2) To compare the changes in an individuals' perceptions about their readiness to return to play (cognitive appraisals) between AVG and traditional rehabilitation protocols,
- 3) To compare the changes in self-reported ankle function of AVG and traditional rehabilitation protocols, and
- 4) To describe the perception of their readiness to return to play (cognitive response), changes in mood states (emotional response), and adherence to the rehabilitation (behavioral response) of AVG and traditional rehabilitation patients throughout the rehabilitation process.

## *Hypothesis*

It was hypothesized that following a 4 week balance training protocol there would be 1) no significant difference in functional measures of static or dynamic balance between a groups, 2) significantly better perceptions about their readiness to return to sport in the AVG

participants, and 3) no significant difference in self-reported ankle function at the end of the 4 week protocol.

### *Scope*

The scope of this study was limited to competitive collegiate athletes with acute LAS and individuals with CAI within an athletic training setting. An athletic training setting often provides access to rehabilitation up to 5 days a week without financial obligation. This setting limits the generalizability of the findings to those with ample access to sports medicine professionals.

### *Assumptions*

Participants' responses on a number of self-reported measures are assumed to be truthful and honest answers and not what the participant thinks the investigators want or expect to find.

### *Limitations*

The current study was limited by a small sample for collegiate athletes who sustained an acute LAS. As a result, the generalizability of the results was low. Multiple clinicians were utilized and efforts were made to standardize treatment but variations were present. The population for the CAI condition was a heterogeneous sample of varying activity levels and athletic backgrounds. A particular measure was completed by the principle researcher evaluating the performance of the participants. The researcher could not be blinded to the group assignment as he was also the treating clinician. This could have theoretically led to a degree of researcher bias.

### *Significance of the study*

The results of this study provide framework for a larger scale evaluation of the use of AVG as an adjunct to the rehabilitation of ankle sprains incorporating both physical and psychosocial aspects of rehabilitation. This may provide a useful modality that can be part of a multidisciplinary approach to the functional and psychosocial rehabilitation of sports injuries.

### *Conflict of interest statement*

The current study was not funded by Microsoft. There is no conflict of interest associated with this study.

## Chapter II: Literature Review

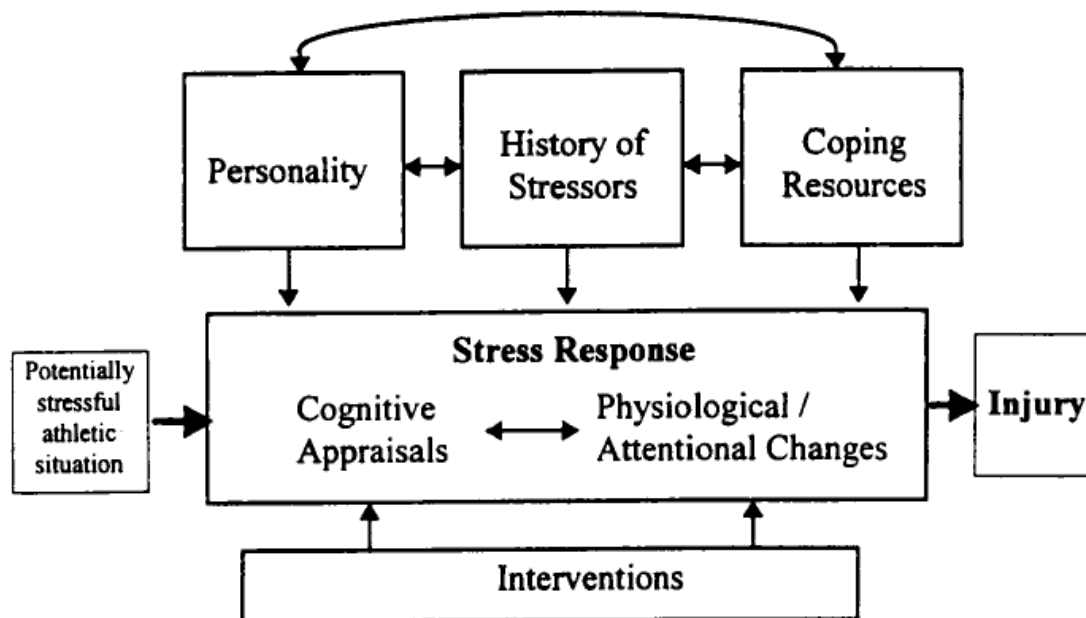
### *Study Framework*

The current study and subsequent literature review will be structured utilizing the biopsychosocial model of sports injury rehabilitation (Brewer et al., 2002) as a theoretical framework to help underpin the rationale of the study. This model, which will be explained in detail in a later section, helps explain the myriad of biological, physical, psychological and social factors that can have an influence on the injury rehabilitation process and its overall outcomes. This review of the literature will first discuss factors that may lead to ankle injuries sustained during physical activity, then discuss the background of the injury of interest, lateral ankle sprains, followed by a review of the existing literature on the potential psychosocial responses that may follow an injury. The review will then discuss the rehabilitation process highlighting key factors, from both physical and psychosocial perspectives, that must be accounted for during the rehabilitation process, including the use of active video gaming within the rehabilitation protocol, and finally the injury rehabilitation outcomes.

### *Injury Antecedents*

Many people around the world participate in sports and recreational activities for improved health, relaxation, or the joy of competition but with participation in these activities also comes the risk of potential injury (Uitenbroek, 1996). These activities can add stress to the body both physically and psychologically depending on the situation (M. B. Andersen & Williams, 1988; Williams & Andersen, 1998). In 1988, and later revised in 1998, Anderson & Williams proposed the Stress and Injury model to help explain why some injuries occur. This model (Figure 1) illustrates the effects that psychological factors outside the sport itself may have impact on injury risk. For example, an increased level of stress in one's daily life may lead

**Figure 1.** Stress and Injury Model (Williams & Anderson, 1998)



to a poor cognitive appraisal of a possibly stressful athletic event. This may then lead to negative attentional or physiologic changes, such as decreased situational awareness or increased muscle tension. These factors combine to increase the risk of potential injuries.

### *Injury Background*

#### *Epidemiology*

An injury in sports and exercise is commonly defined as an event that occurs during a competition or practice causing a participant to refrain from practice or competition for at least 24 hours (Albinson & Petrie, 2003; T. E. Andersen, Floerenes, Arnason, & Bahr, 2004; Emery & Meeuwisse, 2010; Fousekis et al., 2012; Hootman et al., 2007; Knowles et al., 2007; McGuine et al., 2011; McGuine, Hetzel, Wilson, & Brooks, 2012). Participation in collegiate sports has grown in recent history. From 1988 to 2004, the rate of participation increased by 80% in women's sports and 20% in men's sports. The injury rate per athlete-exposure (one athlete participating

in one practice/game equals one athlete-exposure) has remained stable over the same time span when averaged over all sports (Hootman et al., 2007). An assumption can be made that the injury rate for LAS has remained stable during the subsequent nine years from 2004-2013 as descriptive epidemiological studies regarding ankle sprains in US collegiate sports are not available for this time period. The increase in participants leads to an increase in athlete-exposures. While the rate of injuries has remained the same, the number of injuries has increased with the increase in participants (Agel et al., 2007).

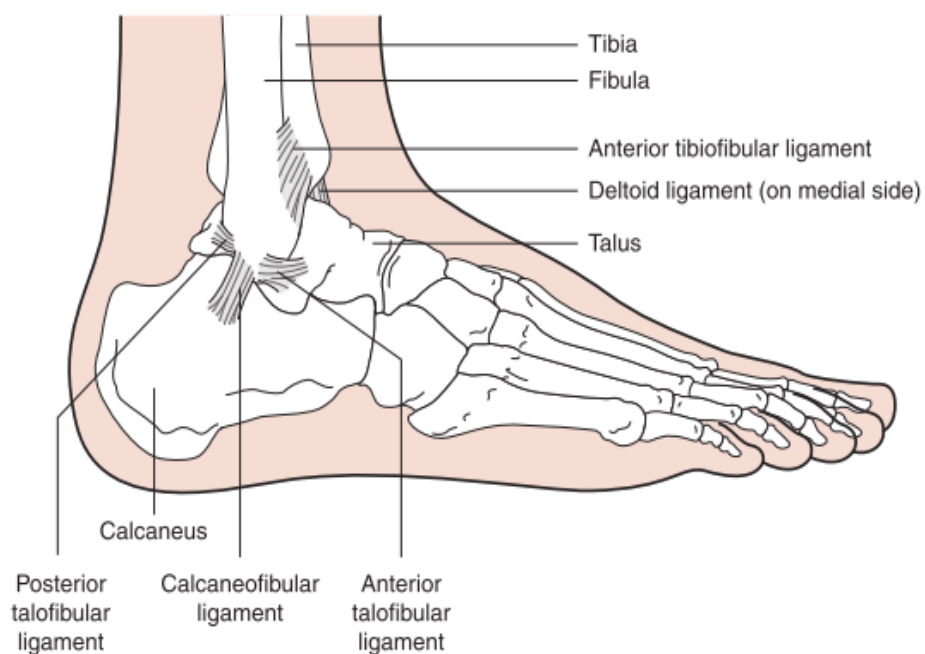
Of all injuries, the ankle is one of the most commonly injured joints of the body, especially in sports participation (Agel et al., 2007; Aoki et al., 2012; Fong et al., 2007; McGuine et al., 2011; McGuine et al., 2012; Zöch et al., 2003). Several epidemiologic studies have been performed in the last 30 years with generally similar results finding that the majority of injuries to the ankle are ligamentous sprains (Agel et al., 2007; Aoki et al., 2012; Fong et al., 2007). Direct comparison of the results across epidemiology studies can be challenging due to the variance of how incidence rate has been reported; using per 1000 person-hour, 1000 person-year, 1000 person-season, or 1000 person-exposure methods (Agel et al., 2007; Aoki et al., 2012; Fong et al., 2007; Hootman et al., 2007; McGuine et al., 2011; McGuine et al., 2012; Yang et al., 2012). Nonetheless, the incidence of ankle sprains has been shown to be highest in sports that involve quick changes of direction and landing activities (McGuine et al., 2011; McKay et al., 2001; Zöch et al., 2003), such as soccer or basketball (Fong et al., 2007; Hootman et al., 2007).

### *Anatomy*

In order to fully appreciate the etiology of mechanism of injury and risk factors for ankle sprains, an in depth knowledge of the ankle joint anatomy is necessary. The ankle, specifically the talocrural joint, is comprised of the distal ends of the tibia and fibula and the talus (Figure 2).



Multiple ligamentous structures support the ankle. Medially, the deltoid ligament connects the tibia to the talus and calcaneus and prevents excessive eversion. The tibia and fibula also articulate together at the ankle joint. This area of articulation is supported by the distal tibiofibular ligament and the lower leg interosseous ligament. The lateral ankle is supported primarily by three ligaments, the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and the posterior talofibular ligament (PTFL) which help to prevent excessive inversion at different joint angles (see Figure 1) (Hertel, 2002; Matharu et al., 2010; Renström & Konradsen, 1997). The ATFL runs from the anterior aspect of the lateral malleolus at an anteromedial angle to the talus and prevents anterior translation of the talus, inversion in plantarflexed positions, and internal rotation of the talus on the lower leg. The CFL runs from the lateral malleolus inferior and posterior to the calcaneus and prevents inversion in neutral



Note: Three groups of ligaments support the ankle joint; the lateral ligament complex (consisting of the anterior talofibular ligament, posterior talofibular ligament and calcaneofibular ligament), the medial (or deltoid) ligament complex and the tibiofibular (syndesmotic) ligaments.

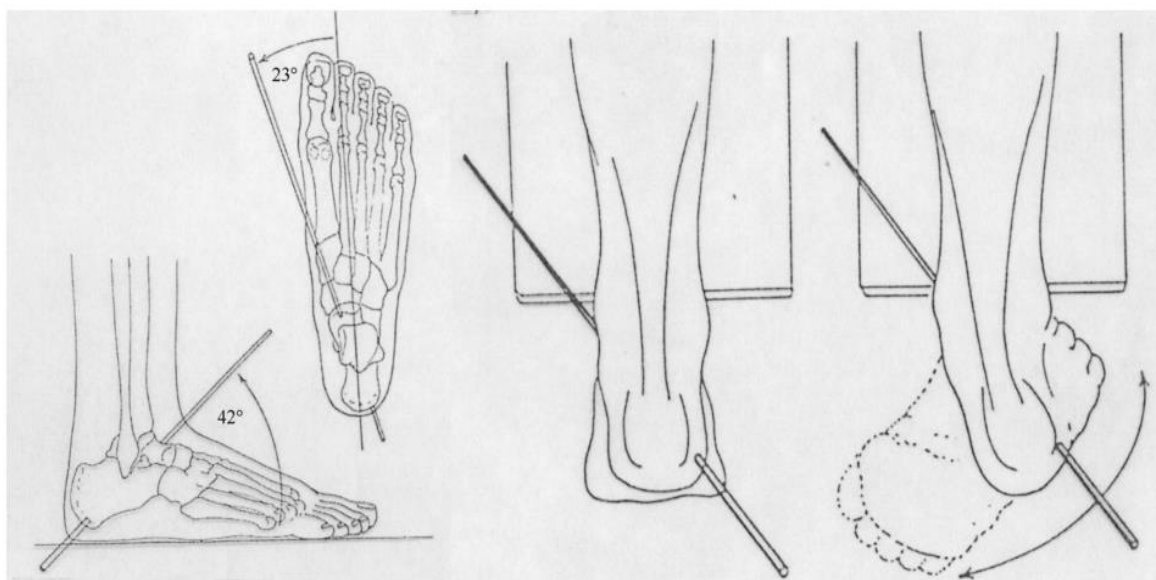
**Figure 2.** Anatomy of the ankle joint (lateral view)

Matharu, et al., 2010

or dorsiflexed position. The PTFL runs from the lateral malleolus posteriorly to the talus and prevents excessive posterior translation of the talus, inversion in dorsiflexed positions and external rotation of the talus on the lower leg (Hertel, 2002).

Though the ATFL and CFL are stabilizers of the talocrural joint, the effects of the subtalar joint and its motions cannot be overlooked when discussing lateral ankle sprains. The subtalar joint is the articulation of the talus on the calcaneus. The axis of the subtalar joint, 42° upward and 23° medially oriented (See Figure 3) allows for a greater amount of supination to occur than does the talocrural joint (Hertel, 2002). The ATFL and CFL assist to limit excessive inversion and internal rotation, two motions that occur in the subtalar joint. The CFL in particular has no attachment to the talus therefore not making it a true talocrural stabilizer (Renström & Konradsen, 1997). While this is generally the case, attachment of the anterior portion of the CFL to the talus has been reported (Hertel, 2002). According to Hertel (2002) while the subtalar joint has extensive ligamentous support, it is poorly understood.

The musculature that acts on the talocrural joint to perform movement at the ankle also act as secondary, or dynamic, stabilizers of the joint. The peroneal, or fibularis, muscles are responsible for concentric eversion and eccentrically controlling the rate of supination. In addition to the peroneus longus and brevis muscles, the dorsiflexors, anterior tibialis and extensor hallucis and digitorum, also help to eccentrically control the rate of supination by slowing the plantarflexion component of supination (Hertel, 2002; Renström & Konradsen, 1997). Medially, the posterior tibialis concentrically inverts the foot and eccentrically controls the rate of pronation and are assisted by the flexor hallucis longus and flexor digitorum (Renström & Konradsen, 1997).



**Figure 3:** Subtalar joint axis

(Hertel, 2002)

The anatomy of the talocrural joint during weight bearing allow the articular surface to provide 100% of the stability when the joint is fully loaded, as well as 30% of the rotational stability. This occurs primarily due to the close packed position of the ankle while fully loaded and may suggest that the ankle becomes unstable during loading and unloading phases, such as landing from a jump or planting to cut (Renström & Konradsen, 1997).

While the ankle has a high level of joint congruity it remains an often injured joint. The anatomy of the ankle, particularly the axis of rotation of the talocrural and subtalar joint, predisposes it to a common mechanism of injury, inversion. This mechanism in turn creates stress to specific structures within the ankle.

### *Mechanism of Injury*

The most common mechanism of injury to the ankle is excessive supination, involving plantarflexion, inversion, and internal rotation of the foot. As previously mentioned, the ATFL is the primary restraint to inversion when the foot is plantarflexed. This commonly leads to the ATFL becoming the first ligament injured during a lateral ankle sprain. Further inversion may

subsequently injure the CFL. The PTFL is typically only injured in severe injuries with accompanying fracture or dislocation (Hertel, 2002; Renström & Konradsen, 1997). Following a rupture to the ATFL studies have shown a marked increase in internal rotation which increases the stress on the remaining intact ligaments, particularly the CFL which is the second most commonly injured ligament (Hertel, 2002).

The physiologic cause of a lateral ankle sprain is an increased supination moment about the subtalar joint. A supination moment about the subtalar joint is dependent on the magnitude and position of the vertical component of the ground reaction force (GRF) during initial foot contact. When the center of pressure (COP) of the foot is medial to the subtalar joint axis, the GRF, also passing medial to the axis of rotation of the subtalar joint, produces a supination moment. To help counteract this supination moment the lateral ligaments, statically, and the peroneal muscles, dynamically, create a pronation moment about the subtalar joint. If the supination moment exceeds this pronation moment, inversion and internal rotation of the rearfoot will occur, likely resulting in injury to either the lateral ligaments or the peroneal muscles or both (Hertel, 2002).

Conversely, in a study that captured an accidental ankle sprain while performing scientific testing found that in the trial in which the ankle sprain occurred, the COP had translated 5 centimeters laterally compared to two previous trials by the subject prior to the ankle sprain (Kristianslund, Bahr, & Krosshaug, 2011). Though the authors did not note the difference between the lateral COP displacement and previous literature, a possible explanation for this discrepancy may be attributed to the horizontal velocities present in performing a cutting maneuver compared to a jump landing maneuver where forces act primarily vertical. If the horizontal components of the subject's motion, decelerating lateral motion over the foot,

and the GRF, crossing medial to the subtalar joint axis, a supination moment may still occur. The authors did show that the eversion moment at the ankle did not exceed 0 Nm in stark contrast to the control trials (Kristianslund et al., 2011), a probable result from an increased initial inversion moment without an increased reactive pronation response.

Research investigating possible physical factors that predict ankle sprains has been conflicting. Risk factors for injury are often viewed as either intrinsic or extrinsic in nature. Intrinsic factors that have shown correlation to ankle sprains have been higher postural sway, lower eccentric ankle strength (Fousekis et al., 2012; Witchalls, Blanch, Waddington, & Adams, 2012). Extrinsic factors showing correlation have been the shoe type worn and the amount of jump landing or cutting required by the activity (McGuine et al., 2011; McKay et al., 2001). The majority of studies show that previous history of ankle injury is one of the strongest predictors of future injury (Fousekis et al., 2012; McKay et al., 2001; Witchalls et al., 2012). There has been conflicting findings on the influence of anthropometric factors, such as BMI, height, or weight (Fousekis et al., 2012; McKay et al., 2001).

The mechanism of excessive supination leads to strains to the ATFL and CFL above the physiologic limits of these ligaments. This results in varying degrees of damage to the ATFL and CFL. As soon as this damage occurs to the ligaments the inflammatory process begins to repair the damaged ligaments.

### *Tissue healing*

Following an injury to the ATFL or CFL, the body utilizes multiple stages in order to heal the damaged tissue. The first stage, hemostasis, begins immediately with the release of platelets to slow and control the loss of blood and fluid caused by the ruptured ligament. This process may last from hours following the injury to up to five days. The presence of the platelets near

the site of injury allows the second stage, chemostasis, to occur. In this stage, which can last from 1-30 days, platelets interact with the injured extracellular matrix to make the platelet-derived growth factor. This substance is essential to bring the onset of proliferation, bringing fibroblasts to the injury site. The third stage, the migration of fibroblasts to the site of injury begins the production of collagen. An uninjured ligament is made of Type I collagen fibers. The collagen synthesis following the injury is made up of Type III collagen fibers. This production of Type III collagen following an injury can last for 5-30 days. During this process the new collagen is laid in a random and disorganized pattern. The final phase is the remodeling, or maturation, of this disorganized collagen matrix. This process lasts for months, up to years, and will not fully organize the new collagen fibers. This results in a loss of structural strength that the original ligament held (Cárdenas Sandoval, Garzón-Alvarado, & Ramírez Martínez, 2012).

There are certain limitations when conducting research on the healing processes of the human body. Animal models may be used as analogs to human subjects but results cannot completely translate to processes in the human body. Human testing often comes with a high cost and many ethical issues that may not make it possible (Cárdenas Sandoval et al., 2012). As a result computer models have been developed to evaluate these processes while bypassing the ethical issues of human testing. However, assumptions are made concerning different elements of the healing process. Some values of the process, such as the concentration of fibroblasts, needs to be estimated and the process as a whole must be simplified. Taking these limitations into consideration, models are still able to correlate with clinically evaluated timelines of the healing process (Cárdenas Sandoval et al., 2012). Therefore, the timeline for treatment and rehabilitation is based on the physiological healing timeline.

There is also evidence to suggest that in many cases (22/40, 55%) those who sustain an ankle sprain may not seek medical treatment (McKay et al., 2001). The lack of treatment may have a negative effect on the total healing of the ligament. Application of stresses to the joint can help the new collagen fibers to properly align to the stresses that will be applied to the ankle (Cárdenas Sandoval et al., 2012). Following a significant injury to the ATFL and CFL a patient may experience a decrease in dorsiflexion. Denegar & Miller (2002) suggest that this may be due to the talus being subluxed anteriorly due to the lack of ligamentous restraint. If this subluxation is not appropriately addressed the ruptured ligaments may heal in an elongated position, compromising its ability to provide mechanical stability and proprioceptive information (Denegar & Miller, 2002). Altering the conception of the rehabilitation setting into a positive situation may offer more opportunities for clinicians to address these deficits.

### *Concomitant Injury*

While the primary damage during an ankle sprain is to ligamentous structures, it is also important to recognize the presence of possible secondary injuries and resulting conditions. Injuries to structures other than the ligaments, such as mechanoreceptors, muscles and nerves, can complicate the recovery process and must also be addressed to assure a full recovery. The following section will discuss these secondary injuries in detail.

Following an ankle sprain, patients often exhibit a loss of postural stability. This has been shown to be a result of damage to the mechanoreceptors present in the injured ligament. Histologic studies have shown that there is a significant amount of Type II and Type III mechanoreceptors in ankle ligaments compared to Type I or Type IV mechanoreceptors. Type II mechanoreceptors sense the initiation of movement of the joint and Type III mechanoreceptors sense the extremes of movement whereas Type I mechanoreceptors provide sensory input for

static posture and Type IV are nociceptive, or pain, sensors. Damage, specifically to the Type III mechanoreceptors, may impair sensory input when the ankle approaches the limits of motion thus impairing the body's ability to counter these forces by activation of the appropriate dynamic stabilizers (Michelson & Hutchins, 1995). This may suggest that neuromuscular training may be most effective when performed in different positions throughout the ROM of the ankle joint.

At a more macroscopic level, when the ankle is forcefully dorsiflexed and inverted with the reflexive contraction of the peroneal muscles to combat this motion, acute subluxation of the peroneal tendons may occur (Maffulli, Ferran, Oliva, & Testa, 2006; Roth, 2010). The resulting force from this event may damage the superior peroneal retinaculum, the primary restraint against peroneal subluxation (Roth, 2010). Tissue healing following a significant injury to the superior peroneal retinaculum may result in elongation of the structure with a more anterior attachment site on the lateral fibula, allowing a "pouch" for the peroneal tendons to sublux into (Maffulli et al., 2006). While this may only occur in 0.3-0.5% of ankle sprains in the United States (Butler, Lanthier, & Wertheimer, 1993), it is believed to be under diagnosed clinically and mistaken for a lateral ankle sprain (Maffulli et al., 2006).

Along with subluxations of the peroneal tendons, tearing of the peroneal tendons may also occur as a result of superior peroneal retinaculum insufficiency. Injury to the superior peroneal retinaculum occurs at the onset of a lateral ankle sprain and may go undiagnosed. This can lead to longitudinal tearing of the peroneus brevis tendon as it repeatedly rubs against the sharp posterior edge of the fibula during gait (Karlsson & Wiger, 2002).

In some cases patients may complain of paresthesia, gastrocnemius or peroneal weakness, or burning pain. These symptoms may point to injury to the common peroneal nerve.



An ankle sprain resulting from a plantarflexion and inversion mechanism causes an increase in strain and excursion of the superficial peroneal nerve (Johnston & Howell, 1999; O'Neill, Parks, Walsh, Simmons, & Miller, 2007). Functional changes have been shown to occur in peripheral nerves after as little as 6% strain in rabbit subjects (Wall et al., 1992). Cadaveric studies investigating the amount of superficial peroneal nerve strain during the ankle sprain mechanism of plantarflexion and inversion showed strain increased as the force applied increased. In ankles with an intact ATFL these strains reached 11.6%. Ankles with a severed ATFL showed strains up to 16% (O'Neill et al., 2007). These studies provide evidence that the most common mechanism of ankle sprains is also a mechanism for superficial peroneal nerve injury and persons with compromised ATFL integrity may be at higher risk for a peripheral nerve injury.

These concomitant injuries add to the difficulty in the treatment of ankle sprains and must be addressed in order to have a successful rehabilitation outcome. Likewise, the athlete's psychosocial reactions to the injury also effect the treatment and outcome of the injury itself (Brewer et al., 2002).

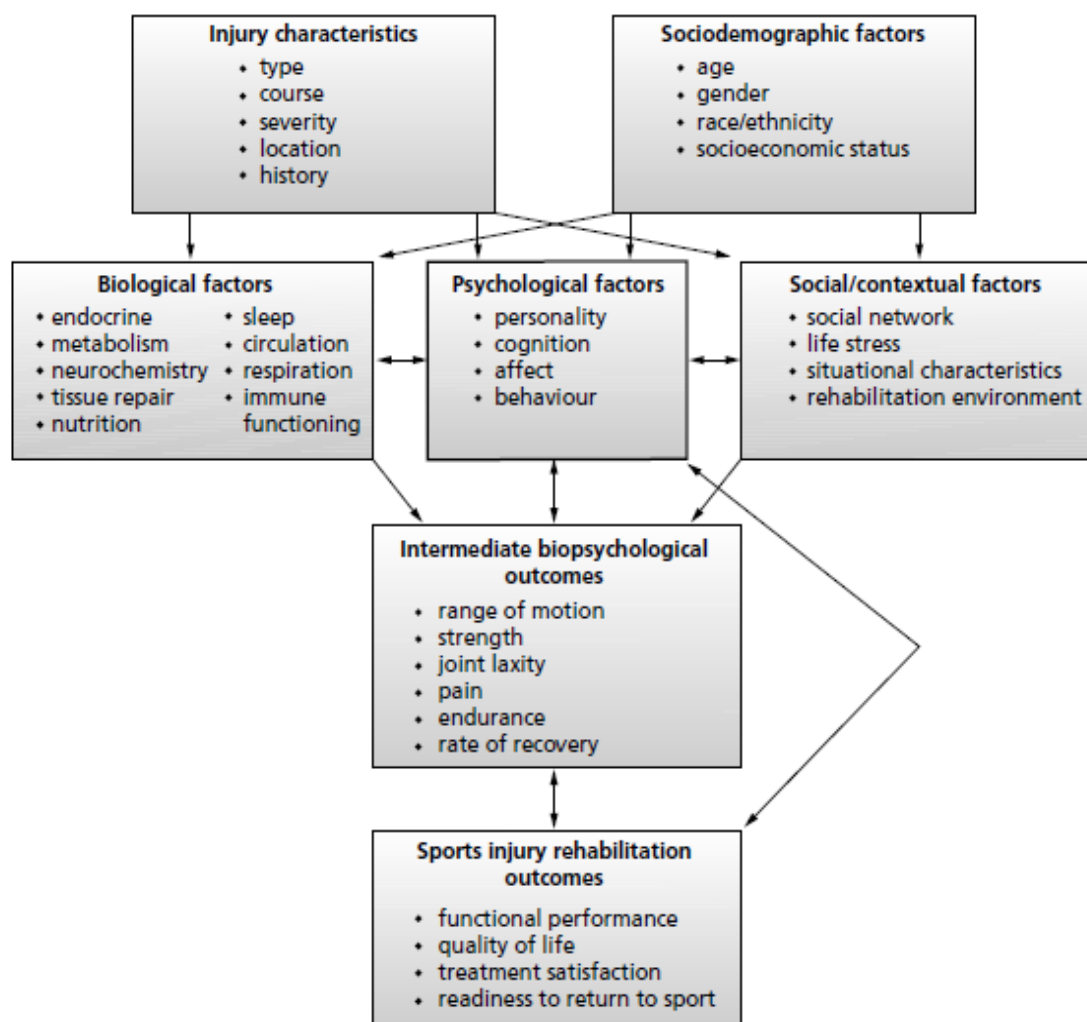
### *Psychosocial Reaction to Injury*

In addition to physical symptoms resulting from the ankle sprain, when injured, many athletes also experience a number of psychosocial reactions to the injury and its subsequent rehabilitation. It has been argued that of all injured athletes, a vast majority are psychologically affected by their injuries (Arvinen-Barrow et al., 2007). These can include changes in cognitions (e.g. appraisal of the injury or self-efficacy in sport upon returning to full participation), emotions (e.g. frustration, depression, or anxiety), and behaviors (e.g. adherence to rehabilitation or impacts on relationships) which can affect their life outside of sports (Granito

Jr, 2001). The impact of these psychological aspects can directly affect their rehabilitation outcome and will be discussed in detail in a following section.

Following injuries, athletes experience a range of both physical and psychosocial reactions which can vary depending on the severity of the injury. Physical symptoms of injury have long been recognized and are commonly visible (e.g. swelling, bruising, functional deficits). Just like many factors influence the physical responses to an injury, there are many different factors that can influence one's psychosocial response.

Brewer, Anderson, & Van Raalte (2002) proposed a biopsychosocial model of sports injury rehabilitation that helps illustrate the factors that can influence the psychosocial responses (See Figure 4). The model suggests that injury characteristics and sociodemographic factors influence biological, psychological and social/contextual factors. For example, a severe injury that occurs during one's final competitive season may lead to a lack of sleep, poor cognitive appraisal of the injury, and increased life stress (Brewer et al., 2002). The core of this model, the psychological factors, stems from earlier work performed by Wiese-Bjornstal, Smith, Shaffer, & Morrey (1998). The elements within the psychological factors, the cognition (cognitive appraisal), affect (emotional response), and behavior (behavioral response) maintain a cyclic relationship of causality. Changes in any of these factors will have a causal effect on the remaining two factors, for instance, negative mood states can result in negative behavioral response (withdrawal from team activities) and negative cognitive appraisals of the injury (decreased confidence to return to play) (Wiese-bjornstal, Smith, Shaffer, & Morrey, 1998).



**Figure 4:** The biopsychosocial model of sports injury rehabilitation (Brewer, Anderson, et al., 2002)

The biological, psychological and social/contextual factors, while having influence on each other, also influence the intermediate biopsychological outcomes and ultimately the rehabilitation outcomes (e.g. lack of sleep and slowed tissue repair decreases rate of recovery or increases life stress causing a negative emotional state may lead to poor adherence to the rehabilitation protocol increasing the risk for re-injury and the development of CAI). The biopsychological outcomes also have the ability to influence the psychological factors (e.g. perceived poor recovery progress negatively affecting cognitive appraisal of the injury and

recovery), as does the rehabilitation outcome (e.g. readiness to return to sport affecting the cognitive appraisal of their ability in future athletic situations) (Brewer et al., 2002; Brewer & Cornelius, 2003; Walker & Heaney, 2013). This model is somewhat limited when explaining the relationship of different psychological aspects within the psychological factors category (Brewer et al., 2002; Walker & Heaney, 2013). However what it does explain is the complexity of how different anatomical (e.g. severity and other characteristics of the injury), biological (e.g. tissue healing, nutrition, etc.), psychological (e.g. cognitions, emotions, and behaviors) and social factors (e.g. life stresses, rehabilitation environment, etc.) all contribute to the intermediate and final recovery outcomes (Brewer et al., 2002).

As displayed in these previous sections, physical and psychosocial factors contribute to the onset of injury, characteristics of the injury, as well as the reaction to the injury. Therefore, the key to improving the outcomes of rehabilitation and preventing the recurrence of ankle sprains may be to use these models as a framework for the complete physical and psychosocial rehabilitation of ankle sprains.

### *Rehabilitation Process*

In order to ensure a complete injury rehabilitation outcome, physical and psychosocial factors must be addressed. The following section will first discuss the physical interventions across the three phases of rehabilitation; the acute phase, the rehabilitation phase, and the return to sport phase. It will then discuss incorporating treatment for the psychosocial impacts of the injury along with the physical treatment. Finally this section will look at how active video gaming may be a useful tool to help improve total sports injury outcomes.

A review by Hertel and Denegar (1998) suggested that multiple areas need to be addressed in the neuromuscular rehabilitation of athletic injuries. Their review showed a

consensus that pain inhibits neuromuscular control and that effusion can decrease motor activity. This led to a recommendation that rehabilitation should involve these steps: 1) Protection, rest, ice, compression, elevation (PRICE) to control swelling, 2) regain range of motion (ROM), 3) restoring volitional muscle contractions, 4) improving reflex responses and strengthening, and 5) retraining of pattern-generated movements (Hertel & Denegar, 1998).

### *Acute Phase*

The first step in the rehabilitation process is the acute stage. The goals of this stage are to decrease pain and swelling and protect the ankle from further injury with protection, rest, ice, compression, and elevation (PRICE) and to regain full ROM (Hertel & Denegar, 1998). Conflicting evidence on the effects of cryotherapy are present within the literature (Bleakley, McDonough, & MacAuley, 2008; Hubbard & Denegar, 2004; Kerkhoffs et al., 2012). It appears that effects of cryotherapy on pain levels is generally positive but its effects on swelling, range of motion and return to play times is inconclusive. The methodology of such studies has also been poor, more quality studies are needed to truly determine the effects of cryotherapy (Hubbard & Denegar, 2004). Computer simulations have suggested that controlling swelling with cryotherapy may increase the concentration of fibroblasts and other healing elements brought to the joint due to the injury thus speeding up healing time (Cárdenas Sandoval et al., 2012).

Regaining full range of motion is important to regain the normal arthrokinematics of the joint (Hertel, 2002). Early introduction of ROM exercises has been shown to improve patients' self-reported outcomes in the short term with no ill effects in the long term (Bleakley et al., 2010). As previously mentioned, if the talus is subluxed anteriorly due to a lack of restraint from the torn ATFL, it will not glide posteriorly during dorsiflexion and will cause a decrease in dorsiflexion range of motion. Therefore, restoring the normal range of motion and kinematics is essential to a full recovery (Denegar & Miller, 2002). Early manual mobilization has been shown

to have positive effects on dorsiflexion ROM following an acute ankle sprain (Bleakley et al., 2008; van der Wees et al., 2006).

### *Rehabilitation Phase*

The beginning of the rehabilitation phase is marked by when pain and swelling have decreased and pain-free ROM has increased. At this point strength training begins. Strength is needed to ensure that the musculature of the lower leg can adequately support the ligaments that were damaged during the injury (Hertel, 2002) thereby regaining volitional muscle control (Hertel & Denegar, 1998). The use of resistive devices (resistance bands or manual resistance) in open kinetic chain exercises is commonly utilized for regaining strength following an injury (Bassett & Prapavessis, 2007; Collado et al., 2010; Han & Ricard, 2011), some studies finding that eccentric training of the muscles elicits significantly greater strength gains than normal concentric training (Collado et al., 2010). The use of closed kinetic chain exercises have proposed benefits of increasing strength and reducing reflexive latency, particularly of the peroneal muscles, but evidence supporting these claims is lacking (Han & Ricard, 2011). The strength of the evertors is commonly viewed as a factor in CAI (Han & Ricard, 2011). Though individual studies have been inconclusive when finding evertor weakness in unstable ankles, a meta-analysis of these studies showed significantly weaker concentric eversion in subjects with instability and therefore recommend that strength training following an ankle sprain is necessary (Arnold, Linens, de la Motte, & Ross, 2009) and when combined with proprioceptive exercises may decrease rehabilitation time and have prophylactic benefits (Zöch et al., 2003).

Proprioception is needed to allow the body to sense where it is in space, allowing for quicker reflexive responses from the surrounding muscles (Hertel, 2002; Hertel & Denegar, 1998). Balance, or neuromuscular, training is commonly performed by completing various tasks

in a single leg stance (Bassett & Prapavessis, 2007; Emery & Meeuwisse, 2010). Proprioceptive exercises traditionally begin with eyes open on a stable surface and increase difficulty by removing the assistance of vision and adding unstable surfaces (i.e. Airex balance pads, BOSU balls, Dynadiscs, etc.) (Chinn & Hertel, 2010). Research has shown that balance training has preventative effects on recurrent ankle sprains, reducing risk of recurrent sprains up to 60% (Bleakley et al., 2008; McKeon & Hertel, 2008; van der Wees et al., 2006), though this risk reduction is significantly lower in individuals without a history of ankle sprain (McKeon & Hertel, 2008). While quality evidence exists supporting the use of balance training in ankle sprain rehabilitation, no optimal frequency or duration of training exists (McKeon & Hertel, 2008). It has been suggested that exercises should be performed at least 3 times per week to achieve prophylactic benefits and have been shown to continue to be effective with training programs lasting up to 2 years in duration (McKeon & Hertel, 2008)

A recent report found that balance exercises on an unstable surface may not accurately target the mechanoreceptors in the ankle (Kiers, Brumagne, Dieën, Wees, & Vanhees, 2012). In this study, the researchers used muscle vibrators on the calves and lumbar paraspinals of subjects to stimulate the muscle spindles while they stood on a force plate, measuring COP excursion and COP velocity. They performed multiple trials of each perturbation while on solid ground and on a foam pad. They found that while standing on a foam pad the calf musculature was much less active than when standing on solid ground and that the paraspinal muscles become more active while on an unstable surface. This could suggest that when standing on an unstable surface your body bypasses the proprioceptive input from the ankle, deeming it an unreliable source, and adopts a hip strategy for postural control (Kiers et al., 2012). Further research is needed to confirm this finding but clinicians should consider these results when attempting to restore neuromuscular control.

### *Return to Play Phase*

Functional training in this phase is imperative in order to restore normal pattern generated movements (Hertel & Denegar, 1998). Specifically, replicating movements that are demanded by the sport the athlete will return to following the injury. This commonly is achieved by various running, cutting, and jumping maneuvers increasing in speed and complexity (Chinn & Hertel, 2010; Hale, Hertel, & Olmsted-Kramer, 2007; O'Driscoll, Kerin, & Delahunt, 2011). Functional training has been shown to have various beneficial physical effects, including increases in dynamic balance, decreases in plantarflexion angle at initial contact (putting the ankle in a more stable position at landing) and increases in patient-oriented outcomes (Hale et al., 2007; O'Driscoll et al., 2011).

### *Incorporating Psychosocial Treatment*

Along with the physical goals discussed above, different psychosocial goals must also be targeted during these same phases of rehabilitation (Kamphoff et al., 2013). As stated previously, psychosocial factors have the ability to affect the cognitive appraisals and emotional and behavioral responses of an injured athlete throughout the recovery process, thereby affecting the entire rehabilitation process (Brewer et al., 2002; Wiese-bjornstal et al., 1998). The psychosocial goals during each of these phases, and how to incorporate them into the physical rehabilitation will be discussed below.

### *Acute Phase*

During the acute phase of the rehabilitation process, the physical goals are to reduce pain and swelling while increasing ROM. The psychosocial goal in this phase is to promote a positive cognitive appraisal of the injury (Kamphoff et al., 2013). Two factors that can assist the athlete in developing a positive cognitive appraisal of the injury are pain control and injury



education (Kamphoff et al., 2013). Physically reducing the level of pain in an injured athlete will have positive psychosocial effects. According to the biopsychosocial model, pain may influence the amount of life stress (Social/Contextual Factor) thus affecting the athlete's cognitive appraisal of the injury as well as their mood state (Brewer et al., 2002). Modalities commonly used to help control pain (ice, electric stimulation, etc.) often provide opportunities for the clinician to educate the athlete on the injury. Learning more about the injury they have just suffered has been seen as a positive coping method when dealing with injuries (Albinson & Petrie, 2003) which can directly affect their cognitive appraisal of the injury (Wiese-bjornstal et al., 1998). Setting ROM goals can give them day to day measureable objectives to meet the broader recovery from injury to show injured athletes positive changes in their condition (Kamphoff et al., 2013). A positive attitude toward the injury during the rehabilitation process has been shown to be an important characteristic of those who cope well with the injury (Arvinen-Barrow et al., 2007).

### *Rehabilitation Phase*

The rehabilitation phase is commonly the longest portion of the rehabilitation process. The physical goals of regaining strength and neuromuscular control sometimes take an extended period of time to achieve. This lends itself to problems in rehabilitation adherence and motivation. In the context of sports injury rehabilitation, adherence is defined as "the extent to which an individual completes behavior as part of a treatment regimen designed to facilitate recovery from injury" (Granquist & Brewer, 2013, p.42). This definition suggests an active approach by the individual versus merely a willingness to comply with the prescribed treatment plan. During this longer stage of physical rehabilitation when exercises may become repetitive and boring, it is important to increase the variety of exercises (Arvinen-Barrow et al., 2007). Variety in rehabilitation may have may help athletes cope better with their injury which in turn

may positively affect their emotional and behavioral responses, particularly in this stage, a positive mood state leading to adherence to the rehabilitation (Brewer et al., 2002; Wieser et al., 1998).

It is important during this long stage of rehabilitation to monitor the injured athletes mood state, or emotional response. Emotional responses, such as mood disturbances, have been shown to negatively correlate with the adherence of a rehabilitation protocol (Albinson & Petrie, 2003; Brewer & Cornelius, 2003; Granito Jr, 2001). Not only does the emotional response have an effect on the behavioral response of the athlete but the biopsychosocial model suggests that the emotional response can also have an effect on the cognitive appraisal of the injury (Brewer et al., 2002). Helping the athlete maintain a positive attitude regarding the injury can help them improve their adherence to the rehabilitation protocol.

During this elongated phase of injury rehabilitation, it is important to elicit a positive behavioral response. The adherence to a rehabilitation protocol is deemed necessary by sports medicine professionals (Arvinen-Barrow et al., 2007; Clement et al., 2013) and has been linked to successful rehabilitation outcomes following a sports injury (Brewer & Cornelius, 2003; Sluijs, Kok, & van der Zee, 1993). This behavioral response is often a barrier to the treating clinician and one of the main obstacles determining whether or not an athlete will cope successfully with their injuries or not (Arvinen-Barrow et al., 2007; Clement et al., 2013). Estimates of adherence rates range from 40-91% (Brewer et al., 2002; Brewer & Cornelius, 2003; Levy, Polman, Clough, & McNaughton, 2006; Sluijs et al., 1993) with some showing no difference in adherence between various medical conditions (Sluijs et al., 1993; Taylor & May, 1996).

### *Return to Play Phase*

During the return to play phase athletes will be preparing to return to full participation in sport. During this phase of sports specific movements athletes may be prone to issues with their self-confidence to return to their previous level of play following the injury as well as the fear of re-injury (Evans, Hardy, & Fleming, 2000; Kamphoff et al., 2013). According to the biopsychosocial model, this may be a direct result from cognitive appraisal of the injury as well as their mood state. Other factors, such as their personality, the amount of time they've missed or life stresses outside of their sport, may also influence their cognitive appraisal and mood state at this point in the rehabilitation process (Brewer et al., 2002).

In summation, the current physical and psychosocial recommendations during the rehabilitation process for a sports injury are dependent on the phases of rehabilitation. The goals of the acute phase should be to minimize pain and swelling while helping the athlete develop a positive cognitive appraisal of their injury. During the rehabilitation phase, in order to regain muscular strength and neuromuscular control it is important to develop and maintain positive cognitive appraisals and mood states to ensure the athlete is adherent to the rehabilitation protocol. When preparing to return to play, retraining sport specific movements is imperative to regain muscular coordination as well as increase the athlete's confidence to return to play successfully. A novel tool to help with these aspects of rehabilitation may be the use of active video games in the rehabilitation setting.

### *Active Video Gaming in Rehabilitation*

A common problem in the rehabilitation of injuries has been that repetitive exercises become menial and boring (Almari et al., 2010; Meldrum et al., 2012). To address this issue virtual reality systems were developed to aid in carrying out rehabilitation tasks. Virtual reality

has been defined as ‘a high-end-computer interface that involves real time simulation and interactions through multiple sensorial channels’ (Burdea & Coiffet, 2003). These systems, while effective, often had bulky and uncomfortable equipment. These virtual reality devices also had extremely high costs that made these systems inaccessible in many settings (Almari et al., 2010). In 2006, Nintendo released the Nintendo Wii™ which provided a virtual reality gaming console at a fraction of the cost of current virtual reality systems as well as consuming considerably less space.

Of the studies that will be discussed in this section, all have either used the Nintendo Wii™ and Wii Fit™ systems, which utilizes an infrared sensor in a hand held controller, or have developed custom video games; none have utilized the Xbox Kinect gaming system. The Xbox Kinect allows the user to control all relevant game tasks with movements of his or her own body without the need for additional equipment (i.e. controller or balance board). It utilizes a typical RGB camera along with an infrared depth-sensing camera to track full body 3D movements of the player (Bo, Hayashibe, & Poignet, 2011; Chang, Chen, & Huang, 2011). The Kinect has been shown to be comparable to gyroscopes and accelerometers when estimating joint angles (Bo et al., 2011) but less accurate than conventional optical motion capture systems (Fernandez-Baena, Susin, & Lligadas, 2012).

Research on active video gaming (AVG) utilizing the Nintendo Wii™ in a rehabilitation setting has been with subjects of varying disabilities. Research in the use of AVG in the elderly population or the rehabilitation of stroke victims has become increasingly common. Multiple studies on AVG in these areas have not only looked at functional outcomes, primarily balance, but also psychological outcomes, such as motivation or enjoyment (C. S. Bell et al., 2011; Celinder & Peoples, 2012; Fitzgerald et al., 2010; Hsu et al., 2011; Kliem & Wiemeyer, 2010;

Meldrum et al., 2012). These studies all showed that between AVG therapy and traditional therapy no differences in functional outcomes while psychological outcomes were either no different or significantly better in the AVG groups. There has been limited research on the use of AVG in the rehabilitation of musculoskeletal injuries (Baltaci et al., 2012; Fung et al., 2012; Sims et al., 2013). The results from these studies have shown minimal differences in functional outcomes when compared to traditional therapy. This initial evidence shows that the use of AVG has the potential provide similar functional benefits in strength and balance within the context of musculoskeletal injury rehabilitation.

Anecdotal reports of introducing games as a therapeutic modality suggest that increasing a patient's perceived enjoyment during rehabilitation also increase their motivation to carry out the rehabilitation and in doing so increasing one's adherence and compliance (Coyne, 2008; Mickey, 2012). Multiple additional studies contest that subjects' motivation increased due to the enjoyment of playing a game as rehabilitation though these were subjective observations by the researchers (Meldrum et al., 2012; Saini, Rambli, Sulaiman, Zakaria, & Shukri, 2012; van den Hoogen, Ijsselsteijn, & de Kort, 2009) while others quantify subjects' enjoyment of a gaming intervention with the use of the physical activity enjoyment scale (PACES) (Garn, Baker, Beasley, & Solmon, 2012; Hsu et al., 2011; Kliem & Wiemeyer, 2010).

Within the literature regarding AVG and rehabilitation, even though psychological benefits are proposed, few studies have used any theoretical framework nor utilized such an approach in their research designs when investigating and proposing these benefits. The usefulness of AVG in rehabilitation context could be explained and understood using the biopsychosocial model of sport injury rehabilitation. In these previous studies involving AVG in a rehabilitation environment, the researchers were manipulating the rehabilitation environment,

a social/contextual factor in the model. By adding a novel rehabilitation tool to the rehabilitation, the researchers added variety to the traditional rehabilitation protocol, a technique commonly used in successful rehabilitation outcomes (Arvinen-Barrow et al., 2007). This variety in the rehabilitation can have a positive influence on the subjects' emotional response to their injury or condition. Likewise, this positive emotional response can have positive effects on their cognitive appraisal of their injury and the situation as well as a positive effect on the behavioral response, which in the case of the majority of the studies mentioned earlier was viewed as an increase in motivation in their rehabilitation (Brewer et al., 2002). This theoretical rationale is similar to that which will underpin the current study intervention.

#### *Theoretical Rationale for Current Study*

The current study proposes the use of home motion gaming consoles, specifically the Xbox Kinect, as an adjunct to traditional therapy. As discussed throughout this review of the literature, multiple factors play a role in the physical and psychosocial rehabilitation of sports injuries. Using Brewer, et al's, biopsychosocial model of sports injury rehabilitation as the theoretical framework allows for explanation of the expected changes resulting from this intervention. This study targets the rehabilitation environment of the social/contextual factors of the biopsychosocial model.

The addition of variety via AVG during rehabilitation may positively influence the rehabilitation environment. This influence may positively affect the emotional responses of the injured athlete and increase their positive attitude towards rehabilitation (Brewer et al., 2002). If the intervention can elicit a positive emotional response during rehabilitation exercises, it may be able to produce positive effects on the cognitive appraisal and behavioral response of the injured athlete. Positive cognitive appraisals may decrease mood disturbances. In turn, positive

emotional responses may result in positive behavioral responses (e.g. rehabilitation adherence or increased effort and intensity) (Brewer et al., 2002; Wiese-bjornstal et al., 1998).

In promoting a positive response of the psychological factors by manipulating the rehabilitation environment, there may then be a positive effect other factors within the model. If the athlete's mood disturbances are decreased because the use of AVG is received as a fun and different rehabilitation task, it may have a positive effect an athlete's satisfaction with their treatment. This may then promote a positive cognitive appraisal of the injury through the rehabilitation process which may manifest as increasing the athlete's confidence to return to play following the injury. Likewise, if the new rehabilitation tasks presented with AVG are received as new and fun it may also positively affect their behavioral response, possibly increasing their adherence to the rehabilitation protocol and lead to an improved physical and psychosocial rehabilitation outcome (Brewer et al., 2002).

### *Outcome Measures*

Following any proposed intervention it is imperative to be able to evaluate its effectiveness. The current study proposes that physical benefits, static and dynamic balance, of the intervention will be comparable to traditional rehabilitation protocols but may affect a subject's cognitive, emotional, and behavioral responses as well. In order to assess the effectiveness of the protocol multiple functional, psychological, and patient-oriented measures will be necessary.

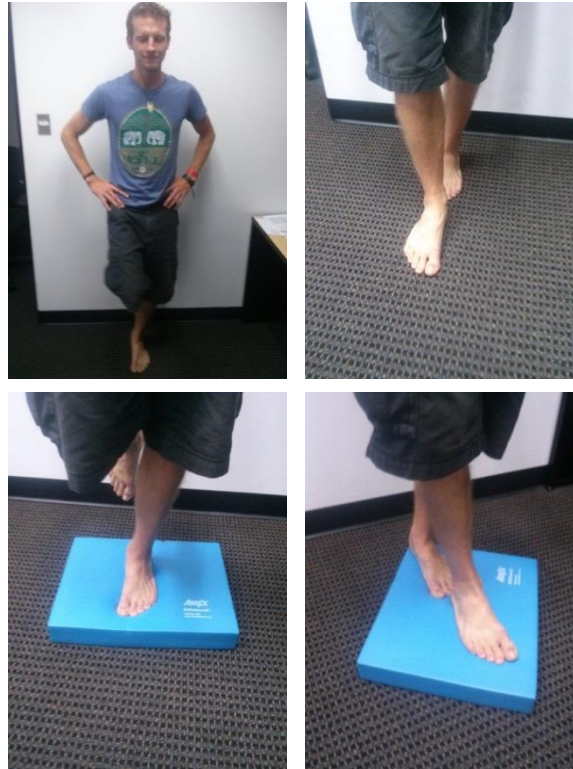
### *Functional*

Various methods of measuring static postural control exist. A common clinical tool for this measurement is the Balance Error Scoring System (BESS). The BESS was originally developed as an assessment tool for concussions and has since been evaluated in the use of ankle injuries

and as a measure for neuromuscular training interventions (Bell, Guskiewicz, Clark, & Padua, 2011; Docherty, Valovich McLeod, & Shultz, 2006; Finnoff, Peterson, Hollman, & Smith, 2009; Hunt, Ferrara, Bornstein, & Baumgartner, 2009). The BESS is performed by a subject completing static stance in various conditions. Three different stances (double-limb, single-limb, and tandem stance) are performed on firm and foam surfaces. The subject is instructed to remain as still as possible for 20 seconds and postural control is evaluated by an examiner using a uniform set of criteria (Docherty et al., 2006; Finnoff et al., 2009).

The BESS has shown to have intratester reliability ranging from 0.50-0.97 in different conditions of the test (Finnoff et al., 2009; Hunt et al., 2009) and intertester reliability from 0.44-0.96 (Finnoff et al., 2009; Riemann, Guskiewicz, & Shields, 1999). Due to the large range of reliability coefficients it is recommended that a single examiner is utilized when performing serial measures (D. R. Bell et al., 2011). Moderate intraclass reliability (0.60) of the BESS is considered to be below conventionally accepted levels (0.75) for clinical measures (Hunt et al., 2009). To improve this parameter the BESS was modified by removing the dual-limb stance conditions as previous research had shown no significant differences between these conditions. This increased the intraclass reliability to 0.71, still below clinically acceptable levels. The addition of multiple trials increased this reliability to 0.81-0.94 (Hunt et al., 2009). Improvements as low as 1 error differences has been considered a minimal clinically important differences for the BESS (Burk, Munkasy, Joyner, & Buckley, 2013). Current recommendations call for a minimum of two recorded trials preceded by a practice trial (D. R. Bell et al., 2011; Hunt et al., 2009).

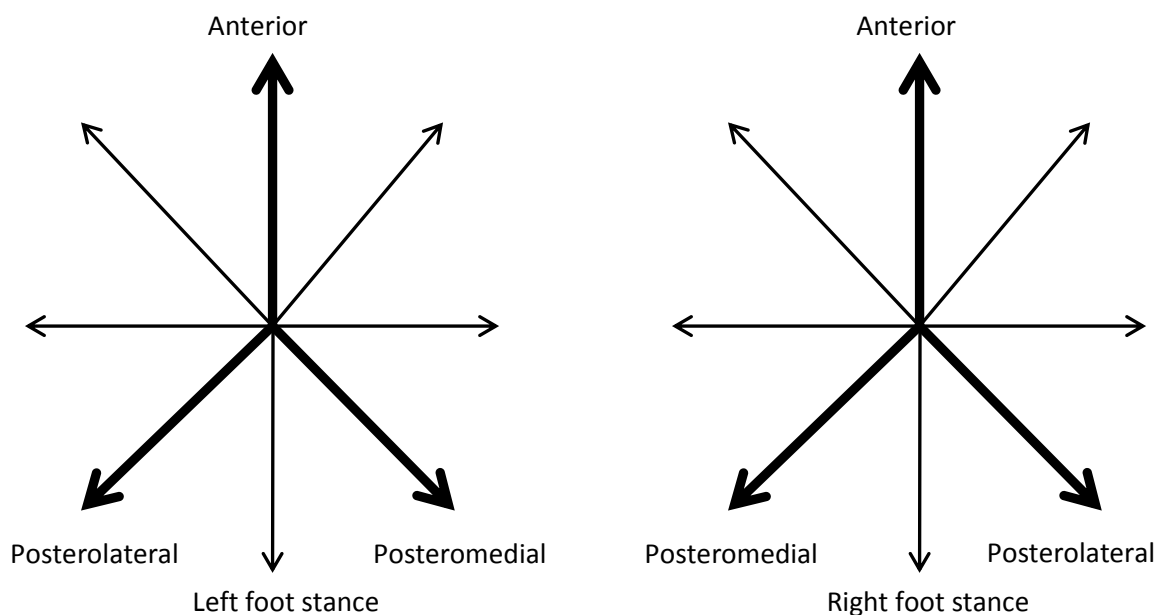




**Figure 5.** BESS stance conditions

Dynamic balance involves a level of expected movement around a base of support. A method that has been commonly used to evaluate dynamic balance has been the Star Excursion Balance Test (SEBT). The SEBT utilizes a series of single legged squats while reaching as far as possible in eight different directions (Figure 6). These directions are named in reference to the stance limb as anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral, and anterolateral, with each direction separated by 45°. These are commonly visualized for the subject by lines on the ground. The subject stands at the center on the involved leg and touches as far down a particular line as possible and return to the starting position while maintaining balance on the stance leg. If the subject at any point during a trial puts weight on the reaching limb to maintain their balance it is to be considered an incomplete trial. The SEBT is measured by distance from the center, or starting point, to the distance reached by the most distal portion

of the reach limb. The farther the distance reached is considered as the higher amount of dynamic stability (Gribble, Hertel, & Plisky, 2012).



**Figure 6.** Star Excursion Balance Test layout.

The SEBT has been proven reliable with intratester reliability estimates of 0.67-0.96 and intertester reliability estimates of 0.35-0.93, the lower intertester reliability estimate was on an initial day of testing and was considered artifact of a practice effect. A practice effect has been shown to occur with the subjects as well. Measurements have been seen to plateau following 4-6 repetitions and the recommendation has since been to allow 4 practice trials prior to taking measurements to assure a practice effect does not introduce error. Factor analysis has also shown a large amount of redundancy when performing the 8 directional SEBT. This has led to the current recommendation of performing only 3 directions of the SEBT, anterior, posteromedial, and posterolateral (Gribble et al., 2012).

When making comparisons across individuals or groups it becomes necessary to normalize the reach values due to variations in subject height. Without normalizing, significant differences can be found between subjects that may be eliminated after normalizing for height. Normalizing for height may be accomplished by using subjects' overall height or limb length, the latter method being recommended. Measuring limb length is done by measuring from the anterior superior iliac spine (ASIS) to the medial malleolus. Measurements are then expressed as a percentage of limb length (Gribble et al., 2012).

The effects of other factors on SEBT performance have also been investigated. Foot type, pes planus, neutral, or pes cavus, has been investigated revealing conflicting evidence. Because of the varying evidence it is not recommended to control for foot type when using the SEBT. It has also been shown that muscle activity varies depending on which direction is being executed (Earl & Hertel, 2001). This evidence may be useful when looking for specific muscular deficits. Gender differences in SEBT performance has been variable, thus, SEBT should not be the sole outcome measure when comparing gender (Gribble et al., 2012).

When giving instructions to subjects regarding how to execute the SEBT it is important to keep restrictions minimal and allow the subject to determine the best movement strategy. Differences in movement strategies may point to functional deficits, for example, a lack of dorsiflexion has been shown to decrease the values of reach in the anterior direction. Decreases in hip and knee ROM in the SEBT have also been linked to CAI. SEBT performance and CAI have been evaluated but results have been variable. This may be due in part to the broad definition of CAI resulting in violation of homogenous subject samples (Gribble et al., 2012).

### *Psychosocial*

*Perceived Readiness to Return to Sport.* A relatively new measure has been developed to assess an athlete's psychological readiness to return to sports participation following an injury. The Injury-Psychological Readiness to Return to Sport (I-PRRS) scale, developed by Glazer (2009), evaluates an athlete's cognitive appraisal of an injury from the perspective of returning to sports participation. The 6 item questionnaire asks the athlete to rate their confidence in different sports related questions. The scale was developed with surveys to athletic trainers and coaches with varying amounts of sport psychology background (Glazer, 2009).

Early descriptive analysis of the I-PRRS showed significant improvements in I-PRRS scores from immediately following the injury to the return to practice and from the return to practice to the return to competition. Content validity was tested by comparing results of the I-PRRS to the Profile of Mood States (POMS) short form. Scores from the I-PRRS and the POMS had significant negative correlations at each of these stages, as the I-PRRS scores increased the total mood disturbance scores from the POMS decreased. Early evidence has shown the I-PRRS to be a valid measure (Cronbach's  $\alpha > .78$ ) when assessing athletes' cognitive appraisal of their injury and its effects on their confidence to return to play (Glazer, 2009).

*Mood.* A measure used to evaluate the mood state of a subject is the Brunel Mood Scale (BRUMS), developed by Terry, Lane, & Fogarty (2003). Derived from the 65 item Profile of Mood States, the BRUMS has subjects assess their current mood by rating specific mood descriptors. This measure contains 6 subscales; anger, confusion, depression, fatigue, tension, and vigor. It is worth noting that the depression subscale is merely an indicator of depressed mood and not clinical depression. Previously known as the Profile of Mood States – Adolescents, the BRUMS has been proven to be applicable to the adult population (Terry, Lane, & Fogarty, 2003).

Confirmatory factor analysis showed adequate fit to the data of four separate samples (adult athletes, adult students, adolescent athletes, and adolescent students) used to validate the BRUMS and that data from four samples was not significantly different. To test criterion validity these four samples also completed various other mood scales, including the original POMS, the Hospital Anxiety and Depression Scale (HADS), the State-Trait Anger-Expression Inventory (STAXI), and the Positive and Negative Affect Scale (PANAS), at the same time as the BRUMS. Strong relationships were present with BRUMS subscales and various measures. Correlations with the POMS showed that the BRUMS and POMS are measuring similar constructs. The BRUMS depression subscale moderately correlated (.57) with the HADS. The vigor subscale correlated well (0.78) with the positive affect of the PANAS while negative affect of the PANAS correlated with the remaining negative BRUMS subscales. The BRUMS anger subscale also correlated highly (0.73) with the STAXI. These correlations provided strong evidence for the content validity of the BRUMS (Terry et al., 2003). Later validity tests produced moderate reliability scores (Cronbach's  $\alpha > .70$ ) (Lan, Lane, Roy, & Hanin, 2012).

*Rehabilitation Adherence.* A measure of rehabilitation adherence made specifically for the athletic training environment is the Rehabilitation Adherence Measure for Athletic Training (RAdMAT). Developed through surveys of 164 athletic trainers and factor analysis by Granquist, Gill, & Appaneal (2010), the RAdMAT is a 16 item practitioner-reported measure. The measure contains 3 subscales regarding attendance and participation in the rehabilitation, communication with the athletic trainer, and attitude and effort in their rehabilitation. Initial analysis showed the RAdMAT to be significantly correlated with the Sports Injury Rehabilitation Adherence Scale, a previously developed, 3-item adherence scale, but has the advantage of being developed specifically for the athletic training setting (Granquist, Gill, & Appaneal, 2010).

While the RAdMAT is a relatively new measure, initial analysis has shown high internal consistencies (Cronbach's  $\alpha > .748$ ) in each subscale as well as the total score. Further initial analysis has shown significant differences between the most, average, and least adherent athlete giving the measure a level of validity (Granquist & Brewer, 2013; Granquist et al., 2010). Validation of the RAdMAT has been retrospective in nature and further prospective evidence is needed.

#### *Patient Oriented outcomes*

Various symptoms of functional ankle instability are subjective and patient reported, such as feeling of giving way or weakness (Hertel, 2002; Hiller et al., 2011). As a result, multiple patient-reporting questionnaires have been developed. These instruments require subjects to rate their function level in various tasks using Likert scales (Carcia, Martin, & Drouin, 2008; Hale & Hertel, 2005; Hiller, Refshauge, Bundy, Herbert, & Kilbreath, 2006). The Cumberland Ankle Instability Tool is a 9-item 30-point scale measuring the severity of functional ankle instability. Scores less than 27 indicate functional instability (Hiller et al., 2006). This questionnaire has been proven reliable (0.83) and excellent test-retest reliability (0.96). The questionnaire also has good sensitivity (82.9%) and specificity (74.7%) for functional ankle instability (Cronkey & LaPorta, 2012; Hiller et al., 2006).

The Foot and Ankle Disability Index (FADI) and Foot and Ankle Disability Index-Sport (FADI-S) use 26-item and 8-item questionnaires. These instruments have been proven reliable with intraclass correlation coefficients of 0.89 and 0.84 respectively and have been shown to be sensitive to improvements in function following rehabilitation in subjects with CAI (Hale & Hertel, 2005). Psychometric analysis has since been performed on the FADI and FADI-S which resulted in five items being removed from the FADI, no changes being made to the FADI-S

(Carcia et al., 2008). The resulting instrument, the Foot and Ankle Ability Measure (FAAM) and the Foot and Ankle Ability Measure Sport (FAAMS) use a 21-ADL item and 8-Sports item questionnaire, respectively. Items are assessed on a 5-point Likert scale with high scores implying high level of function. Both questionnaires have shown good reliability with intraclass correlation coefficients of 0.89 and 0.87, respectively (Arnold, Wright, & Ross, 2011; Carcia et al., 2008). Hypothesis testing suggests the FAAM and FAAMS are appropriate for use with collegiate athletes with CAI (Carcia et al., 2008).

The constructs of these instruments must be noted prior to application and subsequent interpretation. The CAIT questionnaire is considered a discriminative instrument and is to be used in a qualifying manner when classifying subjects (Carcia et al., 2008). Analysis has shown that no single discriminative questionnaire could accurately predict patients that had functional ankle instability (Donahue, Simon, & Docherty, 2011). The FADI and FAAM are evaluative and designed to detect changes over time and are to be used when evaluating changes occurring as a result of an intervention (Carcia et al., 2008).

### *Possible Rehabilitation Outcomes*

Following the completion of sports injury rehabilitation the chance for re-injury still exists. Different physical and psychosocial factors that influence this chance of re-injury, as well as how the current intervention may alter these factors will be discussed below.

### *Chronic Ankle Instability*

When conservative treatment of ankle sprains fails, patients often develop chronic ankle instability. CAI is characterized by repeated bouts of instability, including recurrent sprains, and can be broken down into two categories; mechanical instability and functional or perceived instability (Hertel, 2002; Hiller et al., 2011). Mechanical instability manifests as ligamentous

laxity that is found clinically with various tests that stress the integrity of specific ligaments, such as the anterior drawer or talar tilt tests (Hertel, 2002; Hiller et al., 2011). Functional instability is less clearly defined in the literature, with many authors postulating their own definitions. Many authors agree that there is a subjective component to functional instability that comes from the patient. This has led to Hiller, et al., (2011) recommending changing the term “functional instability” to “perceived instability.” Feelings of “giving out” or weakness, or a self-reported instability are common subjective complaints of those with perceived instability (Hiller et al., 2011; O'Driscoll et al., 2011). Proprioceptive deficits may also play an important role in perceived instability (Hertel, 2002) further stressing the need for balance training in the treatment of LAS to avoid the development of CAI.

Other mechanical changes occur in the joint following repeated ankle sprains seen with individuals with CAI. Arthroscopic examination of ankles revealed the presence of lesions to the articular cartilage in 55%-95% of ankles with CAI, though correlation between the severity of the chondral lesions and the duration of the instability syndrome has been conflicting (Hintermann, Boss, & Schäfer, 2002; Taga, Shino, Inoue, Nakata, & Maeda, 1993). There is evidence that developing CAI brings a greater risk for developing ankle osteoarthritis. Research has shown that CAI alters the biomechanics of the ankle causing altered articular cartilage strain (Bischof et al., 2010). In a healthy ankle, peak strain patterns on the articular cartilage of the talus occur between 4.2-12.4 mm posterior and 0.0-4.6 mm lateral to the middle of the talar dome when 100% body weight is applied (Bischof et al., 2010). In the presence of lateral ankle instability this peak strain pattern deviates to a position 5.2-10.6 mm anterior and 6.3-14.9 mm medial to the middle of the talar dome (Bischof et al., 2010). This is also evident in ankle arthroscopies finding a greater rate of medial talar articular cartilage lesions versus the lateral talar dome (Hintermann et al., 2002).



The development of CAI is often a primary cause of re-injury in lateral ankle sprains. Improvements from balance training programs with individuals with CAI have been significant although confidence intervals for these improvements cross zero, bringing into question the actual effects of the balance training (McKeon & Hertel, 2008). In some instances conservative treatment is insufficient. About 10-20% of patients who have torn either the ATFL or the CFL require reconstructive surgery (Karlsson, Bergsten, Lansinger, & Peterson, 1988; Takao, Miyamoto, Matsui, Sasahara, & Matsushita, 2012).

Conventional rehabilitation programs are designed to provide physical benefits with conservative treatment to avoid surgical intervention. Based on previous literature on the functional outcomes of interventions utilizing AVG in rehabilitation, the current intervention is expected to provide the same level of functional outcomes as conventional rehabilitation programs.

Psychosocial factors may also influence this risk of re-injury. An athlete attempting to return to sport participation before they are fully confident in their injured extremity may experience negative cognitive and emotional effects (M. B. Andersen & Williams, 1988; Williams & Andersen, 1998). The fear of injury may also increase the chance of becoming injured by decreasing their situational awareness when participation in an athletic contest or practice (M. B. Andersen & Williams, 1988; Williams & Andersen, 1998). Along with the risk of re-injury, athletes returning to sport before they are confident enough to do so may exhibit poor performance as they become hesitant to put forth maximum effort and are not completely focused on the task at hand (Evans et al., 2000). The injury that the athlete is recovering from can be viewed as a part of the history of stressors in Williams & Andersen's Stress and Injury model. This increases the stress response as a pre-injury factor, causing a negative cognitive appraisal of the athletic situation, decreasing situational awareness, increasing muscular tension

and thereby increasing the risk of re-injury (M. B. Andersen & Williams, 1988; Williams & Andersen, 1998).

With the addition of AVG to the rehabilitation protocol, it is expected to see an increase in positive mood state as a result. This resulting positive mood state from the addition of variety into the rehabilitation may have positive effects on the athlete's adherence to the rehabilitation protocol and a resulting increase in their confidence to return to their sport. This increase in their confidence may then have positive influence on the pre-injury factors stated above. These physical and psychosocial benefits from the current intervention combine to elicit a better full mind and body recovery following rehabilitation from their injury.

## Chapter III: Methods

In the acute LAS condition, the current study was a single subject, case series design. As a result of the small sample size the study utilized more frequent measurements to evaluate progress during the intervention. In the CAI condition, the current study used a cohort design with repeated measures. The study was set in an NCAA Division I athletic training environment in which injured athletes routinely partake in physical therapy up to 5 times per week.

### *Participants*

*Acute LAS.* Participants with an acute LAS were recruited from the university recognized NCAA Division I men's and women's sports teams. Criteria for inclusion into the present study required sustaining an acute lateral ankle sprain and were otherwise healthy. The definition of an acute ankle sprain utilized for the present study was an injury which was a result of participation in their respective sport, required absence from practice or competitive participation for >24 hours, and was diagnosed as an ankle sprain by either a licensed athletic trainer or physician (Albinson & Petrie, 2003; T. E. Andersen et al., 2004; Emery & Meeuwisse, 2010; Fousekis et al., 2012; Hootman et al., 2007; Knowles et al., 2007; McGuine et al., 2011; McGuine et al., 2012). Participants were otherwise healthy with no active injuries to the knee or hip. Exclusion from the study may occur if (1) a fracture of the lower leg, ankle, or foot is present (if a fracture was suspected it was ruled out by radiologic testing prior to inclusion), (2) the ankle injury resulted in an injury to the distal tibiofibular ligament or syndesmosis, (3) current injury necessitates surgical intervention, (4) the athlete is currently pregnant, or (5) the athlete suffers from a condition affecting the vestibular system.

During the course of the current study only 5 LAS were sustained by varsity athletes at UW-Milwaukee. Three of these injuries were excluded from the study. One also sustained an injury to the anterior tibiofibular ligament (high ankle sprain), one had an active knee injury, and the third LAS was excluded because the principle investigator was not notified until two weeks post injury. Demographic information on the two LAS participants, both female soccer players, is provided in Table 1. Both individuals injured the ankle on their dominant kicking leg. The AVG participant aggravated her injury soon after returning to full participation. This was not a re-injury as there was no known inciting event but rather experienced a drastic increase in pain the following day after participation in a match. The implications of this aggravation are discussed in detail in the Discussion section.

	<b>Participant 1 (AVG)</b>	<b>Participant 2 (Traditional)</b>
<b>Age, yrs</b>	21	19
<b>Height, cm</b>	160.0	170.2
<b>Weight, kg</b>	52.3	58.2
<b>Injury severity</b>	Grade II	Grade I
<b>Sports history</b>	Soccer, Gymnastics	Soccer
<b>Previous # of sprains</b>	2	1

**Table 1:** LAS Demographics.

*Chronic Ankle Instability.* Participants with a history of multiple ankle sprains were recruited from undergraduate and graduate level classes at the University of Wisconsin – Milwaukee and through flyers placed in academic buildings. Criteria for inclusion into the study were a history of acute ankle sprains and a self-reported feeling of instability with a CAIT score of <27. Exclusion from the current study occurred if the participant (1) CAIT score  $\geq$  27, (2) active knee, hip, or back injury, (3) the participant is currently pregnant, or (4) the participant suffers from a

condition affecting the vestibular system. Participants who reported injuries to both ankles were asked to use the ankle they considered to be the worst.

Participants who expressed interest in the study first completed the CAIT questionnaire to qualify for the study. Twenty-one participants expressed interest in the study; one was excluded for scoring too high on the CAIT questionnaire and did not qualify as a functionally unstable ankle. Demographic information for the 20 remaining participants is provided in Table 2. Detailed information on the groups, including ankle sprain frequency, rehabilitation history, mechanical laxity, and experience with AVG is provided in Appendix G. Most participants identified as being recreationally active but no activity requirement was set for the current study. Various athletic backgrounds were identified including basketball, football, baseball, gymnastics, soccer, dance, ultimate frisbee, and recreational running. There was no statistically significant difference ( $t_{18} = .862, p = .400$ ) between the randomly assigned groups in the qualifying CAIT scores. Brief musculoskeletal exams were performed upon inclusion to assess mechanical laxity, ankle strength, and general lower body flexibility. Eighteen participants completed the entire balance training protocol. One participant withdrew for personal reasons while another sustained a lateral ankle sprain outside of the study. Using “Intention to Treat” protocol (Gupta, 2011), the final data points from these participants were carried forward.

	<b>AVG</b>	<b>TRAD</b>
<b>Age, yrs</b>	21.2 ± 2.5	24.2 ± 4.2
<b>Height, cm</b>	172.2 ± 10.3	173.2 ± 10.7
<b>Weight, kg</b>	80.6 ± 24.5	82.4 ± 28.8
<b>Gender</b>	6 F, 4 M	3 F, 7 M
<b>CAIT score</b>	17.6 ± 4.3	16.0 ± 4.0
<b>Mechanical laxity (ATF or CF)</b>	5/10	7/10
<b># Rehabilitation sessions</b>	14.1 ± 1.9	15.5 ± 2.9

**Table 2.** Basic demographic information between CAI groups. Group means ± SD

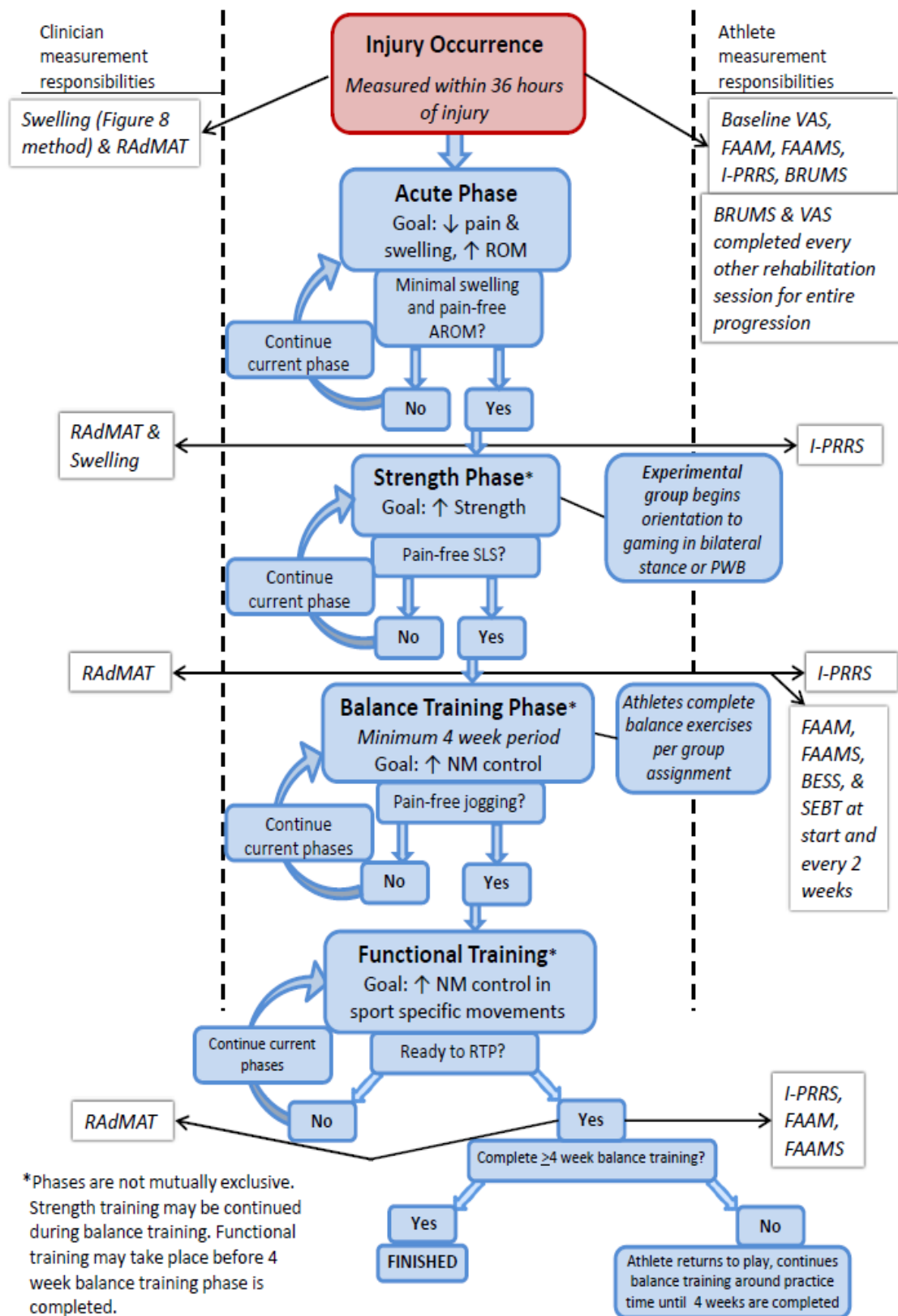
Blinding of participants was not possible due to the nature of the research intervention. Participants admitted to the study were divided into experimental (AVG) and traditional treatment (TRAD) groups by random allocation via random number generator in Microsoft Excel. All participants provided written informed consent and the study was reviewed and approved by the institutional review board at the University of Wisconsin – Milwaukee.

### *Intervention Protocol – Acute LAS*

In the event of an acute ankle sprain in a participant that would meet the inclusion criteria the treating clinician contacted the principal investigator. Layout of the acute LAS protocol and timing of measurements are provided in Figure 7. The principal investigator described the study to the patient and answered any questions prior to providing informed consent. A demographics survey was completed upon inclusion into the study. Participation was strictly voluntary and subjects were able to withdraw from the study at any time.

*Acute Phase.* Following the event of an ankle sprain, primary care, assessment, and decision on the need for further diagnostic testing was provided by the athletic trainers assigned to the respective sport. The severity of the ankle sprain was determined by typical clinical guidelines. A grade I ankle sprain was identified by little swelling or tenderness, little to no functional loss, and no mechanical instability as tested by the anterior drawer and talar tilt tests. A grade II ankle sprain was identified by moderate pain, swelling, and tenderness over the affected tissue, loss of motion and minimal to moderate mechanical instability. A grade III ankle sprain was characterized by severe swelling, hemorrhaging and tenderness, inability to bear weight on the injured limb, limited function and considerable mechanical instability. Baseline scores of the FAAM/FAAMS, pain rating, I-PRRS, BRUMS, and swelling were recorded within 36 hours of the onset of injury. During the acute phase of the rehabilitation process both participants received

**Figure 7:** Flowchart of intervention in acute LAS



the same level of care respective to severity of the injury. Standard treatment protocol during this stage consisted of Protection, Rest, Ice, Compression, and Elevation (PRICE) and early mobilization with passive and active ROM exercises. Research in the application of ice has been conflicting and there is no established optimal treatment duration or frequency (Bleakley et al., 2008). The current study followed common clinical practice of icing for 20 minutes a minimum of 3 times daily but no more than once every hour to allow skin temperature to return to normal. Range of motion exercises included ankle pumps in plantarflexion and dorsiflexion, ankle circles and calf stretches (Bleakley et al., 2010).

*Rehabilitation Phase.* Once pain-free ROM and a reduction to only minimal swelling were achieved, strength training began at the discretion of the treating athletic trainer. A common clinical strengthening protocol was utilized including basic four-way ankle movements with resistive theraband in plantarflexion, dorsiflexion, inversion and eversion. During this stage of rehabilitation, treatment was standard across treatment participants. Exercise protocol was similar to that in previous literature (Chinn & Hertel, 2010; Hale et al., 2007; Powers, Buckley, Kaminski, Hubbard, & Ortiz, 2004). Frequency of treatment during these stages was 3-5 days per week. During the strength training phase, athletes were able to fully weight bear in bilateral stance without pain. At this point the AVG participant began orientating to the Xbox Kinect games to familiarize with its motion-based in-game navigation and demands and objectives of the games to be played. This was done to ensure that game tasks were familiar so proprioceptive challenges could be added during the next phase of rehabilitation and participants could concentrate on balance while executing the games.

The beginning of balance training was marked by the ability to fully weight bear on the injured extremity without pain. The traditional participant performed conventional balance



exercises in single leg stance (SLS) similar to balance exercises performed in previous literature (Holme et al., 1999) as well as lateral movement exercises outlined in Table 3. The AVG participant played the Kinect games while balancing on the injured leg. Games were classified as low, moderate, and advanced exercises. Brief descriptions and proposed purpose of all games are given in Table 4. The participant was allowed to choose between games of same difficulty level, being determined by the treating clinician. Frequency and duration of balance exercises for both participants was 5-7 minute balance sessions 4-5 times per week for a minimum 4 weeks. Total session time lasted 15-20 minutes.

Easy		→ Advanced	
Eyes open, flat ground, 3x30 seconds	Eyes open, unstable surface, 3x30 seconds	Eyes open, unstable surface with ball toss, 3x30 seconds	Eyes closed, Bosu ball, 3x30 seconds
	Eyes closed, flat ground 3x30 seconds	Eyes closed, unstable surface, 3x30 seconds	Eyes open, Bosu ball with ball toss, 3x30 seconds
	Eyes open, flat ground with ball toss, 3x30 seconds	Bilateral leg plyometric line jumps lateral and front/back, 3x30 seconds	Single leg plyometric line jumps lateral and front/back, 3x20 seconds
		Lateral shuffle, carioca, 3x20 feet, both directions	

**Table 3:** Balance exercises for TRAD

As the participants' condition improved and were able to jog without pain, both received functional training. Functional training consists of sport specific exercises to further ready the injured athlete to return to their sport. Functional exercises contain running, cutting, stopping, and lateral movements which may occur during normal participation in a specific sport. The AVG and traditional participants received similar functional training due to limitations of the Xbox Kinect gaming system.

### ***Intervention Protocol – CAI***

Participants who expressed interest in taking part in the study were first asked to complete the CAIT questionnaire (Appendix A). If their score was <27, the study protocol and demands were discussed in detail and informed consent was obtained. A physical exam evaluating the integrity of the lateral ankle ligaments, muscular strength and ROM at the ankle, and general lower extremity flexibility was performed. Because these participants were not currently injured there was no acute phase and all participants were able to immediately begin balance training. Participants with CAI completed the 4 week balance training protocol from the acute LAS protocol (Figure 7). Upon inclusion into the study, participants completed all measures on their first visit to obtain baseline data. Rehabilitation sessions were completed 3-5 times per week and lasted for 5-7 minutes of balance exercises. Total time for each visit ranged from 15-25 minutes. Exercises for the TRAD and AVG groups were the same as in the LAS protocol's Table 3 and Table 4, respectively.

**Table 4.** Description of AVG games.

Games (Full game)	Purpose	Difficulty	Description
Downhill Dodge (Kinect Sports Season 2)	Weight Shifting	Low	Player skis downhill avoiding barriers by leaning to the left or right, squatting or jumping.
Skiing (Kinect Sports Season 2)	Weight Shifting	Low	Slalom style downhill skiing. Player must shift weight from left to right navigate through gates. Maps have 2-3 jumps per round that can be skipped.
Bowling (Kinect Sports Season 1)	Balance Training	Low	Basic 10 frame bowling game. Players may take traditional bowling step or remain stationary and only use arm swing as in SLS.
Pop Darts (Kinect Sports Season 2)	Balance Training	Low	Pop balloons by throwing darts at them. Pop as many balloons as possible in 30 seconds. Time bonuses can extend rounds to 45 seconds. To be performed in SLS.
Body Ball (Kinect Sports Season 1)	Balance Training	Moderate	Computer serves balls and tells player to hit ball with head, hands, or feet. No time limit on rounds. Continues until player misses 3 balls. To be performed in SLS.

Paddle Panic (Kinect Sports Season 1)	Balance Training	Moderate	Based on table tennis. Computer continuously sends balls that the player must return. Player can return balls with either hand. Rounds are 45 seconds plus any time bonuses. 5 balls returned in a row achieves a 2 second bonus. To be performed in SLS
Pin Rush (Kinect Sports Season 1)	Balance Training	Moderate	Bowling challenge to knock down as many pins as possible in 60 seconds plus any time bonuses. 5 second time bonuses achieved for every 30 pins knocked down. Player may throw balls continuously with both hands. To be performed in SLS.
Smash Alley (Kinect Sports Season 2)	Balance Training	Moderate	Tennis based challenge. Player must hit as many mascots as possibly in 30 seconds. Receive a 10 second bonus for clearing all mascots. To be performed in SLS.
Super Saver (Kinect Sports Season 1)	Balance Training	Moderate	Soccer goal keeper challenge in a penalty kick setting. Stop as many shots as possible until 3 missed attempts. Round has no time limit. To be performed in SLS.
Tennis (Kinect Sports Season 2)	Balance Training	Moderate	Basic tennis match. To be performed in SLS. Players may be in bilateral stance between points to avoid fatigue.
Fruit Ninja Arcade Mode (Fruit Ninja)	Balance Training	Advanced	Slicing fruit that flies through the air while avoiding bombs. Slice fruit with fast arm swings. Rounds last 60 seconds. To be performed in SLS.
Rally Ball (Kinect Adventures)	Balance Training	Advanced	Hit a ball down a hallway to break bricks. Hit the ball with any part of your body as it bounces back to the player. To be performed in SLS.
Target Kick (Kinect Sports Season 1)	Balance Training	Advanced	Soccer penalty kick style challenge kicking the ball to targets within the goal while a goal keeper defends. Rounds last a minimum 40 seconds with time bonuses available. To be played in SLS.
River Rush (Kinect Adventures)	Lateral Movement	Low	Player must navigate a raft down a river by stepping to the right or left and jumping while collecting as many coins as possible. Each map has multiple paths.
Reflex Ridge (Kinect Adventures)	Lateral Movement	Moderate	Travel down railroad tracks while collecting coins and avoiding barriers by stepping left or right, squatting and jumping. Levels may last >3 minutes depending on difficulty.
Bump Bash (Kinect Sports Season 1)	Lateral Movement	Moderate	Volleyball based challenge in which player dodges objects being hit to them by quickly stepping left or right or squatting. Round continues until player is

Soccer (Kinect Sports Season 1)	Return to Play Imagery	Moderate	hit 3 times. Soccer game lasting 5 minutes. While on offense player must quickly decide where to pass the ball before the defense steals it. Defensively, players must try to deflect passes by stepping into the passing lane. Automatically switches to goal keeper when opponent gets close to the goal.
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## *Measurements*

All of the following measurements were taken by both the acute LAS and CAI conditions.

### *Functional*

A brief 5 minute warm up on a stationary bicycle was completed prior to functional testing. Components of both static and dynamic balance were evaluated every 2 weeks of the balance training portion of the intervention. Baseline values were obtained on the first day of balance training for the LAS condition and at the initial visit for the CAI condition.

*Balance Error Scoring System.* Static balance was assessed using the modified BESS. To complete the BESS the athlete stood as still as possible for 20 seconds in 4 different conditions. The participants performed one practice trial in each condition followed by two recorded trials (D. R. Bell et al., 2011; Hunt et al., 2009). The athlete stood in a single leg stance and a tandem (injured foot directly behind uninjured foot) stance on firm ground and also on a foam surface. For the current study a 16"x19"x2.5" (40.6cm x 48.3cm x 6.4cm) Airex foam pad was used for this condition. Subjects stood barefoot with their hands on their iliac crests with their eyes closed while an evaluator watched for errors. An error is defined as of the following: 1) lifting hands off the iliac crests; 2) opening eyes; 3) stepping, stumbling, or falling; 4) moving the hip into more than 30 degrees of flexion or abduction; 5) lifting the forefoot or heel; 6) remaining

out of the testing position for more than five seconds (Docherty et al., 2006). The BESS has shown good inter-tester reliability with ICC values between 0.78 and 0.96 (Riemann et al., 1999). This measure was performed at the beginning of the balance training phase as a baseline and then performed every 2 weeks. Three measurements (1 baseline, 2 during balance training) were obtained during the intervention. Errors committed on the BESS by a participant in each condition for the two recorded trials were totaled and the means were calculated for use in statistical analysis. Individual condition scores as well as the total BESS score were used for analysis (Docherty et al., 2006; Riemann et al., 1999).

*Star Excursion Balance Test.* Dynamic balance was assessed by the SEBT using the 3 direction method of anterior (ANT), posteromedial (PM), and posterolateral (PL). The injured limb served as the stance limb during testing in the acute LAS. In the CAI condition, participants' affected side was used as the stance limb. If the participant reported problems with both ankles, the side they considered to be worse was used as their stance limb. For the anterior direction the subject's toes were behind the apex of the Y while the subject's heel was just in front of the apex for both posterior directions. Each participant was given 6 practice trials in each direction as pilot testing showed more consistency after 6 than with 4 practice trials (Gribble et al., 2012). Following practice trials each subject performed 3 trials that were collected for analysis (Hale et al., 2007). A trial in which weight was transferred onto the non-weight bearing limb, coming to rest on this limb or was unable to maintain their balance, constituted a failed trial. Failed trials were discarded and performed again. Instructions to the subjects were kept minimal, only instructing participants to place their hands on their hips, reach as far as they can with the non-weight bearing limb, and that they may not transfer any weight to that limb.

Trials were measured in centimeters and rounded to the nearest 0.1cm. All reach lengths were normalized by individual's limb length, measured from the anterior superior iliac spine to the medial malleolus. The SEBT has been shown to have high intra- and interrater reliability (Gribble et al., 2012). This measure was performed at the beginning of the balance training phase as a baseline and then performed every 2 weeks. Three measurements (1 baseline, 2 during balance training) were obtained during the intervention. Subjects' maximal reach effort for the 3 previously described directions of the SEBT was recorded. Mean values from the 3 recorded SEBT trials were used for analysis. The VAS was administered prior to and following these measures. This was done to ensure that if poor test performances may have been the result of an increase in ankle pain.

### *Psychosocial*

In order to evaluate psychological effects of AVG on the subjects it is necessary to evaluate changes in their confidence in their readiness to return to sport, and mood, and adherence separately. These effects were measured using a questionnaire for each of these areas.

*Injury-Psychological Readiness to Return to Sport Scale.* In order to evaluate a participant's confidence to return to play, an aspect of a cognitive appraisal of the injury, the Injury-Psychological Readiness to Return to Sport Scale (I-PRRS) was utilized. The I-PRRS is a 6 item questionnaire. Each item response is measured on a 100 point scale at intervals of 10. The total score is the sum of all 6 items and divided by 10 (Glazer, 2009). To simplify this process the current study utilized a 10 point scale for each item. In his guide for constructing self-efficacy scales, Bandura states that "a simpler response format retains the same scale structure and descriptors" (Bandura, 2006). A maximum score of 60 correlates with complete confidence

while a minimum score of 0 correlates with no confidence to return to sport. The questionnaire can be found in Appendix B. While this instrument is relatively new, preliminary evidence has shown reliability coefficients  $>.70$  (Glazer, 2009). The I-PRRS was implemented as a baseline within 36 hours of the initial injury. It was then be repeated each at the start of the strength and balance training phases and finally immediately prior to unrestricted practice participation for the LAS condition. In the CAI condition this measure was performed at the beginning of the balance training phase as a baseline and then performed every 2 weeks. This measure, as well as all surveys in the current study, was completed using a mobile survey application from QuestionPro Online Survey Software (Seattle, WA).

*Brunel Mood Scale.* To evaluate participants' mood state the Brunel Mood Scale (BRUMS) was used. The BRUMS questionnaire (Appendix C), previously known as the Profile of Mood States – Adolescents, contains 24 mood descriptors which the athlete rates on a 5-point Likert scale (0=not at all, 4=extremely) how they currently feel. The 24 descriptors are divided into 6 subscales of anger, confusion, depression, fatigue, tension, and vigor. Each subscale scores may range from 0-16 with 0 showing the athlete is not currently experiencing that mood whereas 16 shows the athlete is experiencing high levels of the indicated mood state. Preliminary evidence has shown adequate fit through confirmatory factor analysis and also has satisfactory construct validity when compared with previously established measures (Terry et al., 2003). The BRUMS was administered every other day throughout the intervention. In the LAS condition the AVG participant completed the measure 18 times and the traditional participant 16 times. The participants in the CAI condition completed an average of 11 times each.

*Rehabilitation Adherence Measure for Athletic Training.* To measure the changes in behavioral response of the participant as a result the Rehabilitation Adherence Measure for Athletic

Training (RAdMAT) was utilized (Granquist et al., 2010). The RAdMAT (Appendix D) is a 16 item questionnaire using a 4-point Likert scale (1=never, 4=always). A lowest possible score of 16 shows that the treating athletic trainer views the actions of the athlete to be not adherent at all while a maximum score of 64 shows the athletic trainer feels the athlete is being completely adherent to the rehabilitation protocol (Granquist et al., 2010). The RAdMAT was designed specifically for use in an athletic training setting making it the most applicable measure of rehabilitation adherence for the current study. While the RAdMAT is a new measure, it has been shown to correlate well with previously established measures of adherence and is able to differentiate between athletes exhibiting low, moderate, and high amounts of rehabilitation adherence (Granquist et al., 2010). The RAdMAT was completed by the clinician treating the participant through an online survey. It was administered following the injury as a baseline and at the beginning of the strength and balance training phases and again when the participant was ready to return to unrestricted activity in practice for the LAS condition. In the CAI condition this measure was completed at the first visit as a baseline and every 2 weeks throughout the intervention.

### *Patient Oriented Outcome*

Pain ratings were collected at every other rehabilitation session using the Visual Analog Scale. This scale asks the participant to rate their level of pain from 0 (*No Pain*) to 10 (*Most Terrible Pain Possible*). This scale has been shown to have a good test-retest reliability (ICC=0.87) (Holme et al., 1999).

*Foot and Ankle Ability Measure.* The FAAM and the FAAMS (Appendices E and F) are measures that are designed to detect changes in ankle function over time, making them appropriate for use during an intervention. These measures were taken in the following 36 hours from the onset



of the injury (LAS) or at the participant's first visit (CAI) and then every 2 weeks of the balance training intervention along with the functional measurements. The FAAM consists of 21 questions and the FAAMS consists of 8 sport related questions in which the participant rates how difficult each task is to complete from 0 (*Unable to do*) to 4 (*No Difficulty*). Though maximum scores are 84 and 32, respectively, the results are typically expressed as a percentage of the maximum score. Therefore, 100% indicates full ankle and foot function without disability. The minimal clinically important differences (MCID) for the FAAM and FAAMS are 8 and 9 points, respectively. These measures have been shown to be reliable when compared with other functional ability questionnaires (Carcia et al., 2008). Scores for this measure are presented as a percentage of the maximum score. At the start of the balance training phase and every subsequent 2 weeks during this phase the FAAM and FAAMS were repeated as well as at the point of returning to unrestricted participation in practice for the LAS condition.

### *Statistical Analysis*

#### *Primary Purpose*

Descriptive analysis in the LAS condition was completed for the two participants to evaluate changes seen as a result of the intervention. Demographic information from the subjects, including age, height, sport, history of ankle injury, and previous experience with Xbox Kinect, was used to describe the sample.

#### *Secondary Purpose*

For the CAI condition, demographic information from the subjects, including age, height, sport, history of ankle injury, and previous experience with Xbox Kinect, was again used to describe the sample. For all statistical testing, SPSS (SPSS Version 20 for Windows; SPSS, Inc, Chicago, IL) was used and the  $\alpha$  level was set a priori at .05.

*Aim 1*

The first aim of the current study was to compare the changes in static and dynamic balance between AVG and traditional rehabilitation protocols. To test this, separate 2x2 ANOVAs were used to compare the dependent variables of static and dynamic balance between the AVG and TRAD groups at the beginning and at the end of a 4 week balance training protocol.

*Aim 2*

The second aim of this study was to compare the effects of AVG and traditional rehabilitation protocols on participants' confidence in their readiness to return to play (cognitive appraisals). This was achieved by using a 2x2 ANOVA comparing the cognitive appraisal of the injury between the independent variables of group assignment.

*Aim 3*

The third aim of the study was to compare the changes in self-reported ankle function of AVG and traditional rehabilitation protocols. This was tested using 2x2 ANOVAs to compare the dependent variables of the FAAM and FAAMS questionnaires between the AVG and TRAD groups at the beginning and at the end of a 4 week balance training protocol.

*Aim 4*

The fourth and final aim was to describe the perception of their readiness to return to play (cognitive response), changes in mood states (emotional response), and adherence to the rehabilitation (behavioral response) of AVG and traditional rehabilitation patients throughout the rehabilitation process. Descriptive statistics will be used to evaluate the effects of the AVG protocol or traditional rehabilitation protocols on these psychological measures collected by the I-PRRS, BRUMS, and RAdMAT questionnaires.

## Chapter IV: Results

### *Acute Lateral Ankle Sprain*

#### ***Functional***

##### *Static Balance*

Error scores from the BESS showed that both participants saw a mild increase in errors from their baseline to week 2 of the balance training protocol followed by moderate decrease in errors by week 4 as seen in Table 5. Total improvement from baseline to week 4 was a decrease of 2 errors for the traditional participant and 1 for the AVG participant.

##### *Dynamic Balance*

Both participants saw similar improvements in the ANT and PL dynamic balance conditions as evaluated by the SEBT (Table 5). In the PM reach condition the AVG participant exhibited a substantially greater increase than did the traditional rehabilitation participant.

Both functional measures from the AVG participant were all taken during her balance training protocol following her setback, the original baseline completed prior to her setback was discarded.

#### ***Psychosocial***

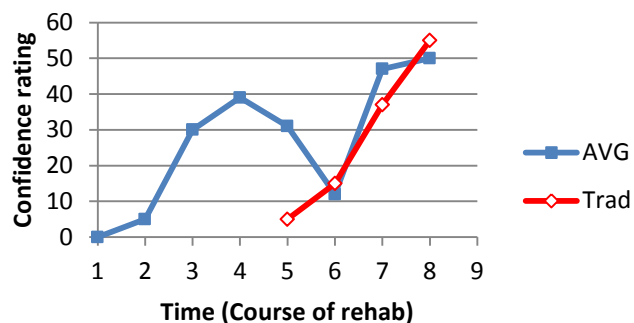
##### *Confidence to Return to Play*

Participants' cognitive appraisal of their injury, specifically their confidence to return to play, measured by the I-PRRS showed the traditional rehabilitation participant had slightly more confidence to return to play following their injury. Figure 8 illustrates the change in each participant's confidence to return to play, recorded at key points in their rehabilitation as discussed previously. The AVG participant's setback took place between the 4<sup>th</sup> and 5<sup>th</sup> measure,

**Table 5:** LAS condition. Static and dynamic balance, I-PRRS, RAdMAT, FAAM and FAAMS post-injury baseline, pre-balance training baselines and changes across balance training. SEBT % - percentage of limb length.

	<b>Injury Baseline</b>	<b>Balance Training Baseline</b>	<b>Week 2</b>	<b>Week 4</b>	<b>Balance Baseline-Wk4 change</b>
<b>BEES (errors)</b>					
<b>AVG</b>	N/A	3	5.5	2	-1
<b>Trad</b>	N/A	12	12.5	10	-2
<b>SEBT ANT (%)</b>					
<b>AVG</b>	N/A	64.10	81.54	83.33	19.23
<b>Trad</b>	N/A	53.73	71.08	74.22	20.48
<b>SEBT PM (%)</b>					
<b>AVG</b>	N/A	60.90	91.03	108.72	47.82
<b>Trad</b>	N/A	73.25	80.24	89.40	16.14
<b>SEBT PL (%)</b>					
<b>AVG</b>	N/A	80.90	99.49	91.79	10.90
<b>Trad</b>	N/A	77.83	79.64	86.27	8.43
<b>I-PRRS</b>					
<b>AVG</b>	0	12	47	50	38
<b>Trad</b>	5	15	37	55	40
<b>RAdMAT</b>					
<b>AVG</b>	59	57	54	56	-1
<b>Trad</b>	50	48	45	46	-2
<b>FAAM (%)</b>					
<b>AVG</b>	12	60	86	81	21
<b>Trad</b>	56	75	98	99	24
<b>FAAMS (%)</b>					
<b>AVG</b>	0	22	59	63	41
<b>Trad</b>	9	41	84	94	53

the 4<sup>th</sup> data point indicating her level of confidence upon returning to full participation for the first time. Values for each data point available in Appendix H.



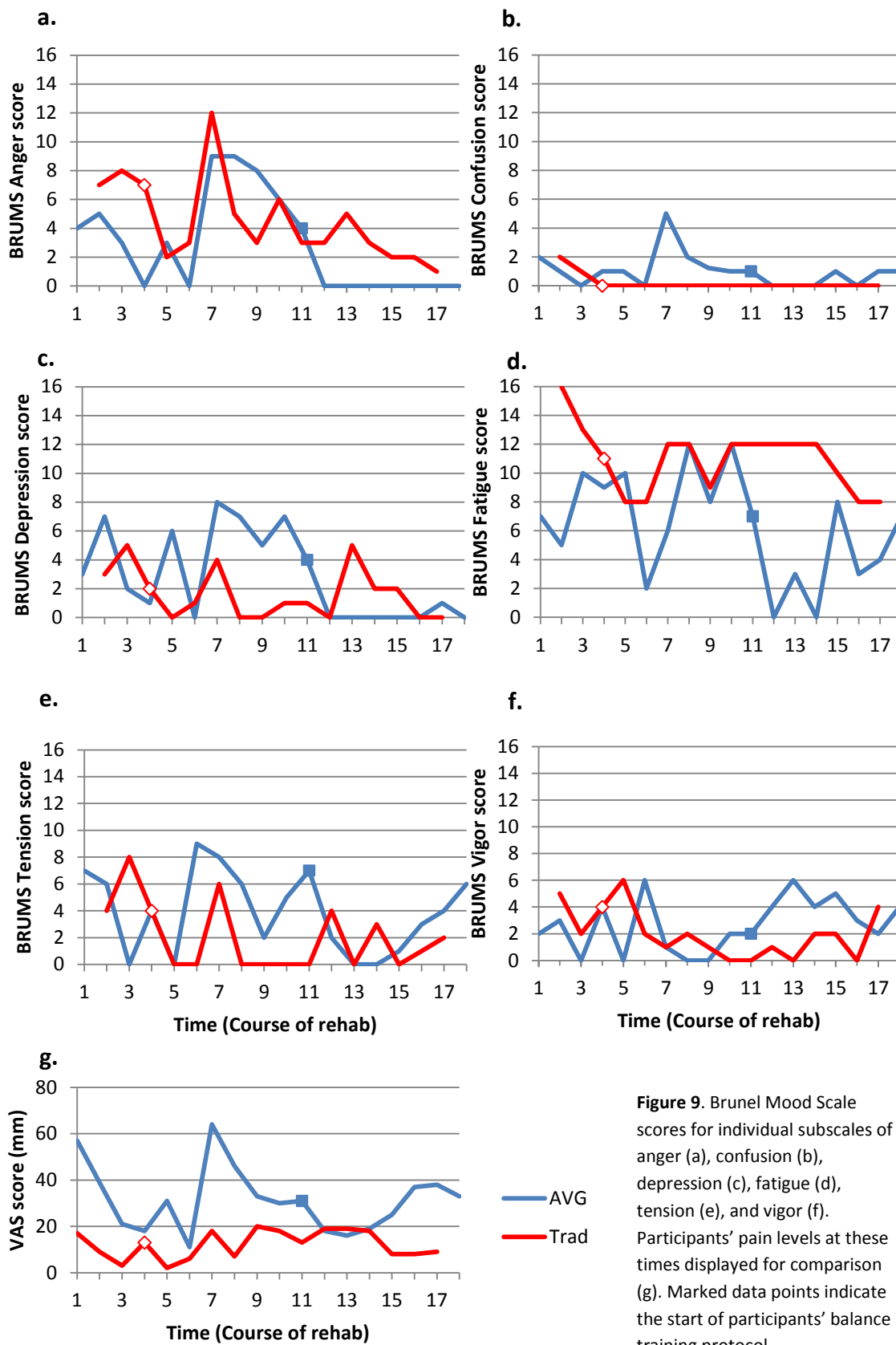
**Figure 8.** I-PRRS confidence rating across course of rehabilitation. Due to differences in length of treatment protocol prior to starting the balance training protocol the number of measures was not equal between participants. The final 3 data points are the same point in time in the balance training protocol.

### *Mood Changes*

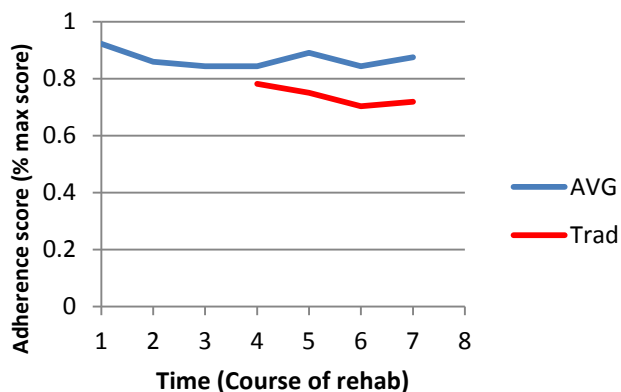
Scores from the BRUMS were separated into individual subscales. Because of difference in the length of rehabilitation and scheduling, individual data points do not coincide with the same point in time between participants (Figure 9a-f). Following the beginning of the balance training portion the AVG participant showed consistently lower anger, depression and fatigue scores as well as higher vigor scores. The setback that the AVG participant experienced occurred between data points 6 and 7 as seen below. At this point marked increases in anger, confusion, depression and fatigue were seen as well as a decrease in vigor.

### *Rehabilitation Adherence*

Participants' adherence to the rehabilitation protocol measured using the RAdMAT showed consistently lower scores in the traditional participant when compared with the AVG participant as shown in Figure 10. The AVG participant's setback occurred between data points 4 and 5 which showed an increase in her adherence following her setback.



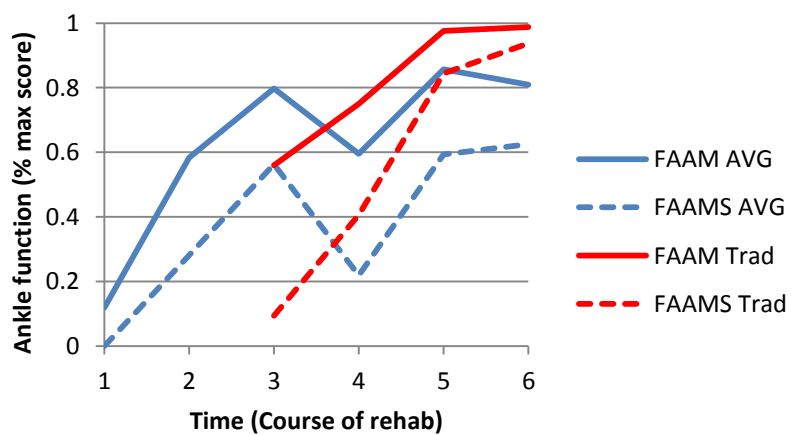
**Figure 9.** Brunei Mood Scale scores for individual subscales of anger (a), confusion (b), depression (c), fatigue (d), tension (e), and vigor (f). Participants' pain levels at these times displayed for comparison (g). Marked data points indicate the start of participants' balance training protocol.



**Figure 10.** RAdMAT scores over the course of the rehabilitation. AVG – Active videogame participant. Trad – Traditional participant. Due to differences in length of treatment protocol prior to starting the balance training protocol the number of measures was not equal between participants. The final 3 data points are the same point in time in the balance training protocol.

### ***Patient-oriented Outcomes***

Self-reported ankle function through the FAAM and FAAMS showed consistently higher scores for the traditional participant (Figure 11). By completion of the balance training protocol the traditional participant scored 98.8% and 93.8% on the FAAM and FAAMS, respectively while the AVG participant scored an 81.0% and 62.5%. The AVG participant's setback occurred between the 3<sup>rd</sup> and 4<sup>th</sup> data points.



**Figure 11.** FAAM and FAAMS scores over the course of the rehabilitation. Due to differences in length of treatment protocol prior to starting the balance training protocol the number of measures was not equal between participants. The final 3 data points are the same point in time in the balance training protocol.

## Chronic Ankle Instability

### Functional

#### Static Balance

There was no significant group by time interaction ( $F_{1,17} = .168$ ,  $p = .687$ ), though participants did significantly improve over time ( $F_{1,17} = 5.427$ ,  $p = .032$ ). Progression of the BESS results across groups over the 4 week protocol can be seen in Table 6.

**Table 6:** CAI condition. Static and dynamic balance, I-PRRS, RAdMAT, FAAM and FAAMS group means (SD) and mean changes.

	Baseline	Week 2	Week 4	Baseline-Wk4 change
<b>BESS (errors)</b>				
AVG	11.2 (6.5)	11.4 (5.3)	10.0 (6.3)	-1.2
Trad	12.0 (8.3)	11.0 (5.3)	9.7 (5.3)	-2.3
<b>SEBT ANT (%)</b>				
AVG	67.5 (8.7)	67.9 (10.0)	70.4 (9.1)	2.9
Trad	64.4 (13.0)	63.2 (6.6)	63.9 (7.0)	-0.5
<b>SEBT PM (%)</b>				
AVG	81.8 (9.4)	85.0 (11.9)	87.1 (10.4)	5.3
Trad	76.3 (13.0)	82.5 (10.8)	83.2 (11.5)	6.9
<b>SEBT PL (%)</b>				
AVG	73.6 (11.4)	79.6 (13.9)	79.8 (11.1)	6.2
Trad	67.1 (16.5)	76.5 (11.6)	76.0 (12.7)	8.9
<b>I-PRRS</b>				
AVG	42.1 (11.2)	44.3 (9.9)	49.2 (9.1)	7.1
Trad	45.0 (5.9)	45.6 (8.1)	50.5 (6.3)	5.5
<b>RAdMAT</b>				
AVG	45.4 (4.4)	49.0 (5.7)	52.3 (5.0)	6.9
Trad	45.8 (3.8)	50.0 (2.7)	51.1 (5.4)	5.3
<b>FAAM (%)</b>				
AVG	87.5 (9.8)	92.3 (3.6)	94.9 (5.8)	5.4
Trad	86.9 (13.8)	90.0 (8.7)	88.7 (11.0)	1.8
<b>FAAMS (%)</b>				
AVG	69.1 (15.1)	82.5 (11.1)	86.3 (11.5)	15.2
Trad	69.4 (22.0)	81.6 (9.7)	84.1 (13.1)	14.7



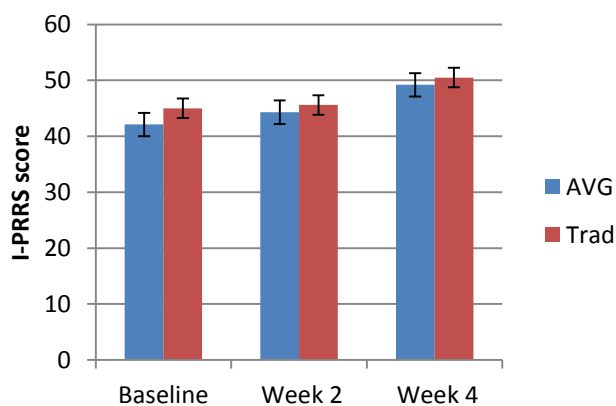
### *Dynamic Balance*

As with the BESS, results from the SEBT showed that there was no significant group by time interaction in the ANT ( $F_{1,18} = .803$ ,  $p = .382$ ), PM ( $F_{1,18} = .262$ ,  $p = .615$ ), or PL ( $F_{1,18} = .598$ ,  $p = .450$ ). Regardless of group assignment participants improved in the PM ( $F_{1,18} = 14.834$ ,  $p = .001$ ) and PL ( $F_{1,18} = 17.943$ ,  $p < .001$ ) directions but did not significantly improve in the ANT direction ( $F_{1,18} = .383$ ,  $p = .544$ ).

### *Psychosocial*

#### *Confidence to Return to Play*

There was no significant group by time interaction in participants' confidence to return to play, measured by the I-PRRS ( $F_{1,18} = .263$ ,  $p = .615$ ) while there was a main effect over time ( $F_{1,18} = 16.285$ ,  $p = .001$ ). Improvements in participants' confidence throughout the rehabilitation protocol can be seen in Figure 12.



**Figure 12.** I-PRRS maximum score 60.

### *Mood Changes*

Individual responses for the BRUMS can be found in Appendix H. Descriptive statistics were utilized due to the amount of repeated measures collected and to visually identify any

effects from the intervention. No discernible trends were seen in either the individual responses or in aggregate group means over the course of the 4 week balance training protocol.

### *Rehabilitation Adherence*

While there was no significant group by time interaction in participants' adherence to the rehabilitation protocol, measured by the RAdMAT ( $F_{1,17} = .239$ ,  $p = .631$ ), there was a main effect over time ( $F_{1,17} = 17.159$ ,  $p = .001$ ). Changes in participants' adherence throughout the rehabilitation protocol can be seen in Figure 13.

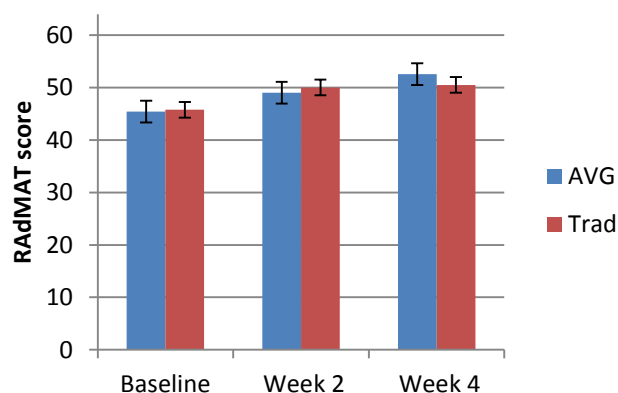
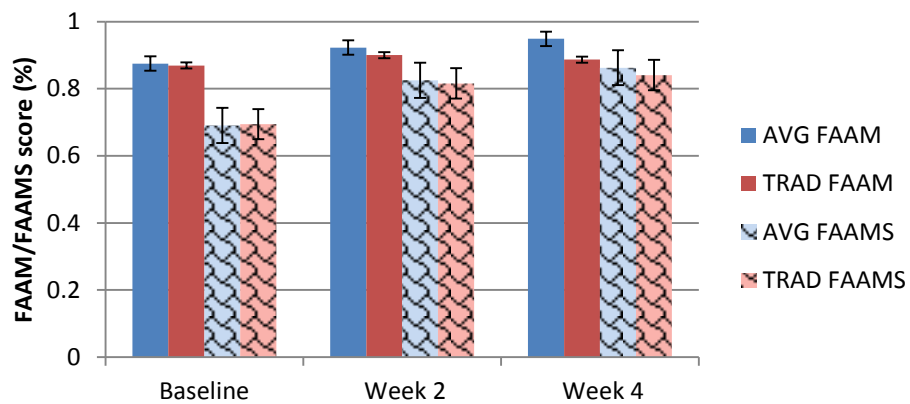


Figure 13. RAdMAT maximum score 64.

### *Patient-oriented Outcomes*

There was no significant groups by time interaction in participants' functional ability, measured by the FAAM ( $F_{1,17} = 2.152$ ,  $p = .161$ ) or the sport specific subscale of the FAAMS ( $F_{1,17} = .275$ ,  $p = .607$ ). Regardless of group assignment, participants did not significantly improve their ankle function in activities of daily living in the FAAM ( $F_{1,17} = 4.127$ ,  $p = .058$ ) but did improve in sport specific activities of the FAAMS ( $F_{1,17} = 15.922$ ,  $p = .001$ ). The AVG group mean improvements for the FAAM and FAAMS were 6.2 and 5.5 while the TRAD group improved by 1.5 and 4.7, respectively.



**Figure 14.** FAAM and FAAMS mean scores across rehabilitation protocol.

## Chapter V: Discussion

### *Acute Lateral Ankle Sprain*

The primary purpose of the current study was to describe the differences in balance improvements, select psychosocial changes, and patient-oriented outcomes between rehabilitation protocols. Similar improvements were made in both static and dynamic balance testing, with the exception of the PM direction in the SEBT, and similar improvements in confidence. Meanwhile the AVG participant showed substantial improvements in mood and consistently higher adherence scores as well as lower ankle function score by the end of the treatment protocol. The significance of these findings are discussed below.

### ***Functional***

#### *Static Balance*

While the AVG and traditional participants improved by one and two fewer errors on the BESS, respectively, the AVG participant performed substantially better than the traditional participant in spite of having a more severe injury. This is likely a result of their athletic background as the AVG participant was a high school gymnast which may have given her a longer history of static balance training than the traditional participant who exclusively played soccer. This difference between sports has been shown in previous literature which saw lower BESS scores with gymnastics when compared with soccer though not statistically significant (Bressel, Yonker, Kras, & Heath, 2007). Additionally, because the AVG participant performed so well at baseline there is a possibility that her potential to improve was limited by the constraints of the BESS.

### *Dynamic Balance*

While previous literature has not found a difference between athletes with gymnastics or soccer backgrounds in the SEBT (Bressel et al., 2007) this may have still been influential in these single subject cases in the large difference in improvements seen in the PM direction. The gains in the ANT and PM by both participants were greater than that seen in previous literature (Hale, Fergus, Axmacher, & Kiser, 2014; McKeon et al., 2008). This is likely a result of the acute injuries causing baseline scores to be lower than those without active injuries.

A gap in the literature exists regarding the progression and gains that are seen during the recovery from an acute LAS which makes it impossible to compare the data seen here with previous literature. Because similar gains were seen with both protocols the data provides some evidence that the use of AVG is as effective as traditional rehabilitation for improving static and dynamic postural control following acute LAS.

### ***Psychosocial***

#### *Confidence to Return to Play*

The participants' confidence in their ability to return to play following their injury show similar paths regardless of their assigned rehabilitation protocol. Both participants had very poor confidence to return to play immediately following their injury had quick increases in their confidence through their rehabilitation process. The traditional participant was slightly more confident to return to play by the end of her balance training protocol but this may simply be a result of having a less severe injury.

The AVG participant's setback occurred following her initial return to full participation in which she reported she was only 65% (39/60) confident to return to play. Following her setback, her I-PRRS scores only decreased by 8 points initially then dropped an additional 19 points when

the measure was repeated two days later. The participant may have been trying to downplay the significance of her setback as a way to cope with the unexpected disruption to her return to play. By the next time she completed this measure she may have had a more realistic cognitive appraisal regarding her perception about returning to her sport. Alternatively, she may have initially considered it to be a minor setback and when quick progress was not seen between the two data collection points her cognitive appraisal of the injury and setback may have become much worse.

Because the I-PRRS is a new measure little research exists on its use in a clinical setting. The author does recommend that I-PRRS scores below 50 may indicate that the athlete is not psychologically ready to return to full activity (Glazer, 2009). The AVG athlete's score of 39 indicated that she may not have been psychologically ready to return at that time. In the current study the I-PRRS was not used as part of the clinical criteria to determine readiness return to play. This particular situation helps show the importance of including the I-PRRS or another objective measure to help identify psychological readiness to return to sport as the AVG participant did not verbalize or exhibit any apprehension upon return to play. Poor confidence to return to play may increase an athlete's stress levels and cause the athlete to either perform poorly or increase their risk for re-injury (Glazer, 2009; Wiese & Weiss, 1987; Williams & Andersen, 1998).

### *Mood States*

Each subscale of the BRUMS provided different insights into the progression of each participant's mood states during the entire rehabilitation process, some more unique than others. Normative data exists for adult athletes but these values were obtained by healthy individuals 10 minutes ten minutes prior to competition (Terry & Lane, 2010) and therefore

cannot be compared to the current sample. The BRUMS showed that both participants' anger and depression scores varied greatly in the early stages of rehabilitation. The participants' scores seemed to be largely influenced by her pain levels at that point in time, when their pain levels elevated so did their anger levels and conversely lower pain levels, lower anger levels. Previous literature has also shown that continued pain may lead to negative emotional triggers such as fear or anxiety (Connolly et al., 2014).

Soon after starting the balance training portion the AVG participant's anger scores ranged only from 0-4 and soon became stable at 0 regardless of her pain level which remained elevated. The traditional participant's anger scores remained slightly erratic, ranging from 1-12 throughout the balance training protocol but did appear to have a decreasing trend within the variance. At the same time the AVG participant's depression scores stabilized at 0 for the majority of her protocol. The traditional participant continued to have erratic scores in this subscale, ranging from 0-5 during the balance training protocol. Because the range was much smaller in this subscale than the anger subscale, no discernible trend was identified. As previous literature has shown that a positive attitude is one of the top characteristics in individuals who successfully cope with injuries (Arvinen-Barrow et al., 2007), helping an individual control these negative mood states is essential for a successful rehabilitation outcome.

The fatigue subscale showed consistently lower scores during the balance training protocol by the AVG participant when compared with the traditional participant. The AVG participant's scores ranged from 0-8 while the traditional participant ranged from 8-12. Prior to starting the balance training protocol the AVG participant's fatigue scores ranged from 2-12, averaging 8.1 across that period versus 4 during the balance training. This would appear that the use of AVG during the balance training portion of her rehabilitation may have had a positive

influence on her state of fatigue whereas the traditional participant's fatigue score remained consistently high during her entire rehabilitation program. This finding has two possible explanations. First, the use of a new modality in the rehabilitation process may have been viewed as a fun or exciting activity which could possibly have had positive effects on their fatigue. Secondly, the use of AVG may have decreased the perception of fatigue resulting from the rehabilitation exercises. An individual achieving the same physical benefits from a rehabilitation program while experiencing less fatigue may decrease overall stress levels thereby improving the injury rehabilitation outcome and possibly decreasing the chance of re-injury.

Scores from the tension subscale did not reveal any obvious trends between participants. Both participants' scores had similar ranges (AVG – 0-7, traditional – 0-6) but had very different paths in obtaining these ranges. The traditional participant reported a level of tension one day and none the next time the measure was completed on multiple occasions. The AVG participant had high tension scores which decreased to zero but then began to increase during the remainder of the balance training protocol. This pattern likely was a result of her injury progress. This same score pattern was seen in her pain rating on the VAS. Because her pain began to increase again her tension scores, specifically subscale mood descriptors of "Anxious," "Worried" and "Nervous," began to increase. This continued pain and subsequent increase in tension has been seen previously (Connolly et al., 2014) and must be addressed to ensure a positive recovery.

In the vigor subscale, the lone positive subscale, the AVG participant displayed higher scores during her balance training phase than the traditional participant with scores ranging from 2-6 and 0-6 and median scores of 4 and 1.5, respectively. It is reasonable to suggest that use of AVG in the rehabilitation protocol allowed the AVG participant to view her rehabilitation



as more fun than traditional rehabilitation which she had done in the past with previous ankle sprains. This modest increase in vigor may still be important for the AVG participant as positive mood has been indicated as a characteristic of those who successfully cope with their injury (Arvinen-Barrow et al., 2007)

A few trends also seemed to emerge between subscales. Subscales of anger and depression showed similar progressions through the course of the rehabilitation process. When the participants' anger increased they tended to also report an increase in depression scores. Alternatively, the vigor subscale, particularly early in the rehabilitation processes, showed that when the participants' anger and depression decreased, their vigor increased. Qualitative research by Tracey (2003) found that 3 weeks following the initial injury participants saw improvements in their emotional states. As emotional states improve following an injury it would stand to reason the subscales of the BRUMS would be less influenced by each other. This would explain the relationship of the vigor and anger and depression subscales early in the rehabilitation process that is not as evident later in the protocol.

In addition to the trends between subscales, trends also emerged between select subscales and pain as measured by the VAS. Particularly early in the rehabilitation process, similar trends were seen in pain levels and anger between both participants. Higher pain levels corresponded with an increase in anger scores. This lends credence to the recommendations made by Kamphoff, et al. (2013) that it is important to help the injured athlete control their pain levels in order to minimize mood disturbances and help foster a positive cognitive appraisal of the injury. When comparing the VAS and depression scores it appears that the AVG participant's scores corresponded to each other while the traditional participant's scores did not seem to show this relationship. Likewise the AVG participant's vigor scores appeared to negatively

correspond with her pain levels, as pain decreased her vigor scores increased during the early stages of her rehabilitation. This was not seen with the traditional participant as her vigor scores remained low for the majority of the rehabilitation process.

The AVG participant's setback, which occurred after only two days of her balance training protocol, also provides some interesting evidence regarding the relationship between mood disturbances and return to play scenario. The participant completed the BRUMS on a Friday (data point 6) while in preparation for her first return to full competitive play later that day. This soccer match was the final regular season match and a win would clinch the regular season conference championship. The AVG participant reported experiencing no anger, confusion, or depression, minimal fatigue and her highest levels of vigor. These scores would indicate that she had very little mood disruption at that time but her tension score showed the opposite. The AVG participant reported her highest scores in the tension subscale, with descriptors like, "Anxious," "Worried," and "Nervous," the day of her first match following the injury. The Williams & Anderson Stress-Injury Model (1998) explains that high levels of stress leading up to a stressful athletic situation have the potential to lead to further injury. This may be corroborated by the situation seen here as the AVG participant experienced a setback following this athletic event. Though the high tension scores do not specify whether they were linked to her ankle injury, the stressful nature of the ensuing match, or a combination of both, the stress-injury model does not limit itself to specific stressors but explains that any stress may lead to increased risk of injury (Williams & Andersen, 1998). This further expresses the need for rehabilitation protocols to not only treat the physical but the psychosocial following an injury.

The AVG participant's set was not a subsequent ankle sprain but rather a substantial increase in pain the day following the match. Radiographic (x-ray and MRI) testing showed no

apparent injury or damage to either bone or muscle and it was continued to be treated as a lateral ankle sprain. Once pain was controlled the AVG participant began the balance training protocol again. Toward the end of the balance protocol her pain levels began to increase once again along with a rise in her tension levels. Long term follow up with this participant showed that the diagnosis was a longitudinal tear of the peroneus tertius that was missed by the MRI.

The differences in these scores during the balance training portion indicate that the use of AVG in the rehabilitation setting may help injured athletes cope with the negative psychosocial effects that may be caused by sustaining physical injuries.

#### *Rehabilitation Adherence*

There are multiple possible explanations for the differences in this measure. First, the AVG participant had a more severe injury than did the traditional participant. This may have led a higher perceived need to adhere to the rehabilitation program and be an active participant in order to achieve a full recovery whereas the traditional participant may have perceived the injury to be only minor and that adhering to her rehabilitation protocol may not be necessary for a full recovery. This injury severity and adherence relationship has been shown previously (Taylor & May, 1996). Second, the AVG participant's adherence scores were initially decreasing early in the rehabilitation process. Following her setback her adherence scores increased likely as a result of the aggravation of her injury and may have caused her to recommit to her rehabilitation protocol. The time at which the participants sustained their injuries may have had an effect on this measure as well. The AVG participant sustained her injury towards the end of the competitive season which gave her a goal of returning for the conference and national tournaments. The traditional participant was injured during off-season workouts when an emphasis on a quick return may not be as important.

The AVG participant's secondary increase in adherence also coincided with the beginning of her balance training protocol. This increase may have been a result of her setback as previously mentioned or may have been a result of the use of AVG in the rehabilitation setting. The AVG protocol allowed the participant to have a degree of control in the rehabilitation process by allowing her to choose the games to play each day. Providing rehabilitation participants with a level of control has been shown to be important in eliciting positive rehabilitation outcomes (Tracey, 2003). Other research has shown that increasing the variety in a rehabilitation protocol can have positive effects on one's rehabilitation outcome (Clement et al., 2013). Adding AVG to a rehabilitation protocol gives an added level of variety into a rehabilitation protocol that isn't necessarily viewed as work but a more entertaining and less repetitive set of balance exercises. Increasing one's adherence to a rehabilitation protocol is paramount for a successful rehabilitation outcome (Clement et al., 2013; Granquist, Podlog, Engel, & Newland, 2014). The use of AVG in a busy athletic training setting, where one-on-one supervision isn't always possible, offers participants a level of autonomy in their rehabilitation that may thereby increase their adherence to the rehabilitation protocol and improve their total rehabilitation outcome (Granquist et al., 2014; Tracey, 2003).

### ***Patient-oriented Outcomes***

The patient-oriented outcomes revealed a pattern similar to the I-PRRS over the course of the rehabilitation. This is not completely unexpected as the questions on these measures are somewhat similar. In the FAAM and FAAMS you are asked to rate how difficult an activity is while the I-PRRS asks you to rate your confidence to perform sports related tasks. Like the I-PRRS, the traditional participant reported higher functional ability by the end of the rehabilitation protocol and is likely a result of the differences in injury severity as the AVG participant showed much lower baseline scores in the FAAM and FAAMS than did the traditional

participant. While the final scores were lower for the AVG participant, the amount of improvement made during the balance training protocol between the AVG (FAAM – 18 points, FAAMS – 13 points) and traditional (FAAM – 20 points, FAAMS – 17 points) were comparable for that time frame of the study. The traditional participant's improvements may have been curtailed by restraints of the measure as she was near 100% for these measures allowing the AVG participant to show greater improvement in the FAAM. The AVG participant showed less improvement on the sport subscale which coincides with the lower I-PRRS scores seen earlier. Because the I-PRRS is a new measure a correlative study between the I-PRRS and the FAAMS has not been done but may be useful.

Improvements by both participant are well over the minimum clinically important difference (MCID) for the FAAM and FAAMS are improvements of 8 and 9, respectively (Martin, Irrgang, Burdett, Conti, & Van Swearingen, 2005). These MCID values were derived from a study using a heterogeneous sample of lower leg injuries and not specifically for acute ankle sprains, therefore the clinical significance of surpassing these MCIDs in this given sample is relatively low.

### *Chronic Ankle Instability*

The secondary purpose of this study was to compare the balance improvements, select psychosocial changes, and patient-oriented outcomes between rehabilitation protocols. No significant differences were seen between groups in any measure and the ramifications are discussed below.

### **Functional**

The lack of difference in balance improvements between groups helps provide evidence for the first hypothesis of the current study that there would be no difference between

treatment protocols in balance performance. Lack of a significant difference between protocols suggests that the utilization of AVG to the rehabilitation of patients with CAI can be an acceptable addition to current treatment protocols, providing similar functional benefits as traditional rehabilitation exercises.

Previous research has shown better improvements in the BESS following a training protocol than the current study (McLeod, Armstrong, Miller, & Sauer, 2009). McLeod, et al., found a reduction of about 3.5 errors following their training protocol. The time parameters of the training protocols may have caused this difference in outcomes. The current study completed balance training 3-5 times per week for 4 weeks, each session lasting a total of about 20 minutes. McLeod, et al, administered balance training 2 times per week for 6 weeks with each session lasting about 90 minutes long. This difference in protocols may have elicited the different results in static balance. The current protocol parameters were selected to resemble a typical rehabilitation protocol in an athletic training room setting thereby increasing the clinical applicability of the results.

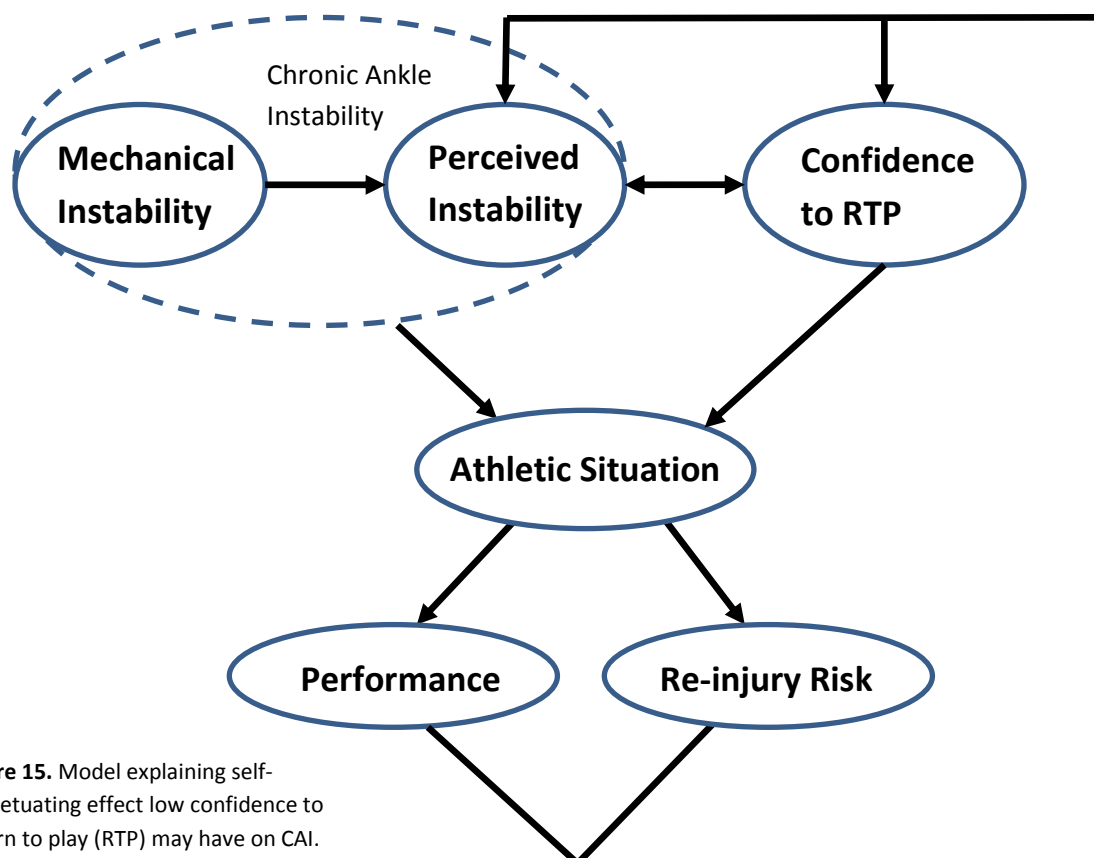
Improvements in dynamic balance were similar between groups as well as similar to previous research (Hale et al., 2014; Hale et al., 2007; McKeon et al., 2008; O'Driscoll et al., 2011; Zech et al., 2014). This provides more evidence to support the first hypothesis of the current study showing that AVG provides functional benefits comparable to traditional rehabilitation. Though multiple studies saw similar improvements, Schaefer & Sandrey (2012) reported different findings in SEBT reach distances. Their rehabilitation group improved their anterior reach by twice the amount seen in the current study. The authors suggested that mobilization improving the subjects' ankle dorsiflexion may have led to the improved anterior reach seen in their study (Schaefer & Sandrey, 2012). While improving ankle dorsiflexion was

not an objective of the current study, only two participants exhibited decreased ankle dorsiflexion when compared to their uninvolved side. Adding a joint mobilization treatment to the rehabilitation protocol of the current study could possibly have provided similar results.

### ***Psychosocial***

#### *Confidence to Return to Play*

The I-PRRS, being a new measure, has not been used to track progress over the course of an intervention. The similar improvements seen by both groups give evidence supporting AVG as a suitable addition to rehabilitation protocols in the treatment of CAI. As discussed above, the author of the I-PRRS recommends that a score below 50 may indicate an individual may not be psychologically ready to return to athletic activities. It is interesting to note that both groups were below this recommended level of confidence to return to play at baseline even though many of the participants were currently recreationally active. Figure 15 helps explain how a low confidence to return to play may perpetuate CAI, particularly the perceived instability discussed previously by Hiller, et al. (2011). Entering an athletic event with low confidence and high amounts of perceived instability, quantified in the current study by the I-PRRS and CAIT, may have deleterious effects on performance and increase risk for re-injury (Hiller et al., 2011; Williams & Andersen, 1998). Likewise, poor performance due to their ankle condition or a fear of re-injury while playing will likely have a negative effect on their confidence to play as well as their perceived instability.



**Figure 15.** Model explaining self-perpetuating effect low confidence to return to play (RTP) may have on CAI.

In order to restore a high level of function this cycle must be broken. In the current study both treatment groups significantly became more confident following the 4 week balance training program. At baseline only 35% of the participants were at a 50 or higher on the I-PRRS. Of the 18 participants who completed the entire 4 week protocol, 61% of the participants were over 50 with both groups showing a mean of about 50. Rehabilitation programs for CAI can help increase one's confidence to return to play and decrease amount of added stressors in future athletic situations. Fewer additional stressors may allow them to focus more on the task at hand, potentially decreasing the risk for re-injury and improving their performance (Williams & Andersen, 1998) resulting in a more complete therapeutic outcome. Furthermore, individuals commonly site pain or health issues as reasons for not participating in physical activity (Aaltonen et al., 2012) and those with CAI have been shown to have lower health-related quality of life scores than uninjured individuals (Arnold et al., 2011). Implementing a rehabilitation program



may increase an individual's confidence to return to physical activity and may improve their quality of life.

### *Mood States*

The treatment protocols did not appear to have an effect on the emotional states of the participants. There are multiple possible explanations for this lack of interaction(Appendix H). Previous research has proposed that experiencing an injury is similar to sustaining a loss (Brewer & Cornelius, 2003). When injured, some athletes feel as though they lose a part of their identity, a Social/contextual factor in Brewer et al's Biopsychosocial model of sports injury rehabilitation (Brewer et al., 2002). This in turn has an impact on their emotional response to the injury as was seen in the LAS condition above. In the CAI condition, most participants were still recreationally active and did not cause them to lose time in their preferred recreational activities during the time of this study. The CAI participants also may not identify themselves as athletes to the same degree as collegiate athletes which may explain why there was no change in their emotional states as their ankle function improved.

Mood disturbances in the CAI group in the current study may have been more related to life events than to their ankle. Emotional responses to life events can commonly have an effect in the rehabilitation setting. The timing in which the measure was completed may have minimized any effects from the rehabilitation that may have resulted. The BRUMS measurements were collected at the beginning of the rehabilitation sessions. Completing this measure either after their rehabilitation session or before and after may have elicited a more noticeable effect between rehabilitation protocols on the participants' moods as well as changes in mood that could be linked more directly to the intervention.

### *Rehabilitation Adherence*

A similar study also showed no difference between a traditional balance training protocol and a balance training protocol utilizing AVG (Vernadakis et al., 2014). While this study measured self-reported compliance to the rehabilitation program, the current study measured adherence from the clinician's perspective. The lack of difference seen here may have been influenced by the construct of the intervention. A commonly reported reason for not adhering to a rehabilitation program is a lack of time (Sluijs et al., 1993). In the current study rehabilitation sessions were scheduled at the convenience of the participants which has been shown previously to associate with higher adherence rates (Brewer, 1998). Additionally, during these sessions the participants were working with a clinician during each visit and were therefore under constant supervision. Different results may have been seen if this study was designed to give the participants a rehabilitation protocol to complete in the athletic training room but not always have one on one time with a clinician.

Likewise, structuring the study around home exercise programs, where patient adherence is a common barrier to successful rehabilitation outcomes (Taylor & May, 1996), may have offered different results. AVG has potential to be used in this setting with positive results in the area of rehabilitation adherence. Vernadakis, et al. (2014), found that the participants found the AVG protocol to be more fun than did participants using a traditional rehabilitation protocol. They also recognized that allowing the participants to choose which games they play gives them a feeling of control in the rehabilitation process which can aid in maintaining rehabilitation adherence and being an active participant in the rehabilitation process (Vernadakis et al., 2014). While adherence to a rehabilitation protocol continues to be a barrier in clinical practice it is also recognized by clinicians as essential to successful rehabilitation outcomes (Arvinen-Barrow et al., 2007). The variety that the use of AVG can bring to the

rehabilitation setting may help keep injured athletes motivated during the entire injury process (Clement et al., 2013)

### ***Patient-oriented Outcomes***

The similar gains in functional ability are more evidence that AVG can be added to a rehabilitation protocol for CAI while offering comparable benefits as traditional exercises. Additionally, AVG may help increase variability in the rehabilitation setting, which has been perceived as important factor in helping athletes cope with their injuries better (Clement et al., 2013). Though both groups did significantly improve over time, they did not meet the MCID for either the FAAM or the FAAMS (Martin et al., 2005). While the group improvements did not meet clinical significance, 6 individuals did meet the MCID for the FAAM (4 AVG, 2 TRAD) as well as the FAAMS (3 AVG, 3 TRAD). The lack of clinical significance may have been partially due to higher baseline scores for some individuals. In order to have an opportunity to individually meet the MCID for these measures the participants baseline would have to be below 77/84 (91.7%) for the FAAM and 24/32 (75%). At baseline only 11 of the 20 participants scored lower than 77 on the FAAM while 13 scored lower than 24 on the FAAMS.

Similar results were seen by Hale, et al. (2007) who reported a 7.3% improvement on the FADI and an 11.1% improvement on the FADI-Sport following a 4 week balance training program with subjects with CAI. Another study that had a control group with CAI perform a 4 week balance training program reported improvements of 11.2% and 13.6% on the FAAM and FAAMS bringing each participant to 100% on both scales (Schaefer & Sandrey, 2012). While the sample from the Schaefer & Sandrey study had similar baseline FAAM scores and higher baseline FAAMS scores, it is possible that the level of ankle instability by their sample was different from that of the current study. Schaefer & Sandrey (2012) determined their subjects'

CAI with an ankle instability questionnaire that does not quantify the degree of instability instead of using the CAIT questionnaire. While the FAAM has been shown to be sensitive to improvements in function following rehabilitation in subjects with CAI, it is not a measure to determine CAI. Comparing differences in the level of instability between these two samples cannot be done so the significance of the differences of these results is unknown.

Improvements in self-reported ankle function may have a similar potential effect on CAI as was discussed with improvements in confidence to return to play. Improving an individual's ankle function through a rehabilitation program may have positive effects on their confidence to return to play as well as decrease their amount of perceived instability. As discussed in Figure 15, this may then have positive effects on their performance upon return to their recreational activities and also decrease the level of risk for sustaining another lateral ankle sprain.

### *Integrated Clinical Care*

In the rehabilitation for acute lateral ankle sprains, the use of AVG in a balance training protocol showed that it can provide comparable functional benefits as traditional balance exercises while also having the potential to decrease the amount of negative mood states that may arise with acute injuries. Helping improve an athlete's mood following an injury and fostering a positive attitude in the rehabilitation setting may have positive effects on their confidence to return to play as well as improve their performance in the rehabilitation. At the same time AVG may improve adherence to the rehabilitation protocol thereby helping to improve rehabilitation outcomes both physically, preparing their body to return to play, and also psychosocially, preparing their mind to return to play. In doing so we may also be able to decrease their chance of reinjury in the future and avoid the development of CAI.

In the rehabilitation of chronic ankle instability, the current study provides evidence that the use of AVG elicits similar improvements in balance, confidence to return to sporting activities, adherence to the rehabilitation protocol, and self-reported ankle function without showing an effect on the emotional states of the participants when compared to the traditional rehabilitation protocol. In spite of a lack of effect on the emotional state of the participants, the addition of AVG to the rehabilitation protocol gives clinicians another modality to help create variety in the rehabilitation setting. This may help patients cope with their injury and possibly improve their adherence according to Brewer's Biopsychosocial model of sports injury rehabilitation even though that result was not explicitly seen in the current study. Improvements seen in these various parameters are essential to a successful rehabilitation outcome of CAI treatment. Improving these areas can help decrease an individual's perception of instability and increase their confidence to return to physical activity. Providing this to individuals with CAI may help improve one's quality of life and allow them the chance to experience the health benefits physical activity participation can offer.

It is important to note that the only two participants reported having negative previous experience with AVG and were randomly assigned to the traditional treatment group. The individual results for those two participants may have been considerably different if they were assigned to the AVG group. Individuals who do not enjoy AVG or video games in general may have an adverse attitude toward the addition of AVG to their rehabilitation. Development of rehabilitation protocols must take the individual into account to provide the best opportunity for a successful recovery.

### *Limitations*

The current study had multiple limitations that must be taken into consideration when interpreting the results. The acute LAS condition had two participants in a case series design. Many of the differences seen here could have been a result of individual differences as well as differences due to injury severity as noted previously. In this situation some studies will adopt a design in which participants will switch treatment protocols half way through the study. This was not done because of the acute nature of the injuries. Switching protocols in the middle of the rehabilitation process would raise the question of if any improvements were a result of the natural healing process or the intervention used at the time. A control group was not used in the design of the current study as denying medical attention following an injury is unethical.

In the CAI condition, no physical activity requirements were set as inclusion criteria. While most of the participants were relatively physically active, some admitted to very little activity. This led to a sample that was slightly nonhomogeneous and may limit the findings. A small sample size with only ten subjects in each group will also limit the findings although few of the measures were even remotely trending towards significance. Procedurally, the BRUMS was taken at the beginning of each rehabilitation session. Had this measure of mood states been completed after each session, or before and after each session, there is a chance that there would have been different findings. As mentioned earlier, the participants were under direct supervision of a clinician during their rehabilitation sessions which may have influenced their rehabilitation adherence scores.

### *Implications for Future Research*

Results for the LAS condition were not able to be compared to previous literature because few research articles exist providing physical therapy treatment to acute injuries, most

often chronic injuries or subjects with a history of injury are used. This illustrates the gap between clinician and researcher but also speaks to the difficulty in access to participants immediately following an injury. Most injuries occur away from the research setting. Researchers working in concert with clinicians may allow for this access to become available more often. In relation to the need for research involving acute injuries, the rate at which balance ability returns following an acute ankle injury would be useful information for clinicians trying to determine safe, evidence-based return to play timelines.

With many different types of therapeutic modalities there is always the chance for responders and non-responders. The use of AVG in a rehabilitation setting is no different. There is the potential for participants who have no desire to play video games and would likely show a different response in measures used in the current study, particularly the BRUMS and RAdMAT measures. Evaluating the effectiveness of AVG with participants who do not enjoy playing video games is warranted.

A clinical area in which the use of AVG has great potential is in home exercise programs, particularly with adolescents who often already enjoy video gaming. Home exercise programs often have low adherence rates with the adolescent population. Evaluating the ability of AVG to improve adherence when patients are given exercises to do when unsupervised is a necessary step in the integration of AVG into clinical practice.

Finally, the I-PRRS is a new measure that has not been used extensively in research up to this point. It was developed for use when returning from an acute injury. Additional research with chronic conditions for this measure is needed as many participants seen in the current study were recreationally active while reporting scores lower than the recommended level for returning to sports activities.

## References

- Aaltonen, S., Leskinen, T., Morris, T., Alen, M., Kaprio, J., Liukkonen, J., & Kujala, U. (2012). *Motives for and barriers to physical activity in twin pairs discordant for leisure time physical activity for 30 years. International Journal of Sports Medicine, 33*(2), 157-163.
- Agel, J., Palmieri-Smith, R. M., Dick, R., Wojtys, E. M., & Marshall, S. W. (2007). *Descriptive epidemiology of collegiate women's volleyball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. Journal of Athletic Training, 42*(2), 295-302.
- Albinson, C. B., & Petrie, T. A. (2003). *Cognitive appraisals, stress, and coping: preinjury and postinjury factors influencing psychological adjustment to sport injury. Journal of Sport Rehabilitation, 12*(4), 306-322.
- Almari, A., Kim, H.-N., Cha, J., & El Saddik, A. (2010). *Serious games for rehabilitation of stroke patients with vibrotactile feedback. International Journal of Computer Science in Sport, 9*, 14.
- Andersen, M. B., & Williams, J. M. (1988). *A model of stress and athletic injury: Prediction and prevention. Journal of Sport & Exercise Psychology, 10*(3), 294-306.
- Andersen, T. E., Floerenes, T. W., Arnason, A., & Bahr, R. (2004). *Video Analysis of the Mechanisms for Ankle Injuries in Football. The American Journal of Sports Medicine, 32*(1 suppl), 69S-79S.
- Aoki, H., O'Hata, N., Kohno, T., Morikawa, T., & Seki, J. (2012). *A 15-Year Prospective Epidemiological Account of Acute Traumatic Injuries During Official Professional Soccer League Matches in Japan. The American Journal of Sports Medicine, 40*(5), 1006-1014.
- Arnold, B. L., Linens, S. W., de la Motte, S. J., & Ross, S. E. (2009). *Concentric Evertor Strength Differences and Functional Ankle Instability: A Meta-Analysis. Journal of Athletic Training, 44*(6), 653-662.
- Arnold, B. L., Wright, C. J., & Ross, S. E. (2011). *Functional Ankle Instability and Health-Related Quality of Life. Journal of Athletic Training, 46*(6), 634-641.
- Arvinen-Barrow, M., Hemmings, B., Weigand, D., Becker, C., & Booth, L. (2007). *Views of Chartered Physiotherapists on the Psychological Content of Their Practice: A Follow-Up Survey in the UK. Journal of Sport Rehabilitation, 16*(2), 111-121.
- Baltaci, G., Harput, G., Haksever, B., Ulusoy, B., & Ozer, H. (2012). *Comparison between Nintendo Wii Fit and conventional rehabilitation on functional performance outcomes after hamstring anterior cruciate ligament reconstruction: Prospective, randomized, controlled, double-blind clinical trial. Knee Surgery Sports Traumatology Arthroscopy.*
- Bandura, A. (2006). *Guide for Creating Self-Efficacy Scales. In F. Pajares & T. Urdan (Eds.), Self-Efficacy Beliefs of Adolescents (pp. 307-337): Information Age Publishing.*



- Bassett, S. F., & Prapavessis, H. (2007). Home-based physical therapy intervention with adherence-enhancing strategies versus clinic-based management for patients with ankle sprains. *Physical Therapy, 87*(9), 1132-1143.
- Bell, C. S., Fain, E., Daub, J., Warren, S. H., Howell, S. H., Southard, K. S., . . . Shadoin, H. (2011). Effects of Nintendo Wii on quality of life, social relationships, and confidence to prevent falls. *Physical & Occupational Therapy in Geriatrics, 29*(3), 213-221.
- Bell, D. R., Guskiewicz, K. M., Clark, M. A., & Padua, D. A. (2011). Systematic review of the balance error scoring system. *Sports Health, 3*(3), 287-295.
- Bischof, J. E., Spritzer, C. E., Caputo, A. M., Easley, M. E., DeOrio, J. K., Nunley, J. A., 2nd, & DeFrate, L. E. (2010). In vivo cartilage contact strains in patients with lateral ankle instability. *Journal of Biomechanics, 43*(13), 2561-2566.
- Bleakley, C. M., McDonough, S. M., & MacAuley, D. C. (2008). Some conservative strategies are effective when added to controlled mobilisation with external support after acute ankle sprain: a systematic review. *Australian Journal of Physiotherapy, 54*(1), 7-20.
- Bleakley, C. M., O'Connor, S. R., Tully, M. A., Rocke, L. G., Macauley, D. C., Bradbury, I., . . . McDonough, S. M. (2010). Effect of accelerated rehabilitation on function after ankle sprain: randomised controlled trial. *BMJ, 340*, c1964.
- Bo, A. P. L., Hayashibe, M., & Poignet, P. (2011, Aug. 30 2011-Sept. 3 2011). Joint angle estimation in rehabilitation with inertial sensors and its integration with Kinect. Paper presented at the Engineering in Medicine and Biology Society, EMBC, 2011 Annual International Conference of the IEEE.
- Bressel, E., Yonker, J. C., Kras, J., & Heath, E. M. (2007). Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *Journal of Athletic Training, 42*(1), 42-46.
- Brewer, B. W. (1998). Adherence to sport injury rehabilitation programs. *Journal of Applied Sport Psychology, 10*(1), 70-82.
- Brewer, B. W., Andersen, M. B., & Van Raalte, J. L. (2002). *Psychological Aspects of Sport Injury Rehabilitation: Toward a Biopsychosocial Approach Medical and Psychological Aspects of Sport Exercise* (pp. 41-54): Fitness Information Technology.
- Brewer, B. W., & Cornelius, A. E. (2003). *Psychological Factors in Sports Injury Rehabilitation*. In W. R. Frontera (Ed.), *Rehabilitation of Sports Injuries: Scientific Basis*. Malden, MA: Blackwell Publishing.
- Burk, J. M., Munkasy, B. A., Joyner, A. B., & Buckley, T. A. (2013). Balance Error Scoring System Performance Changes After a Competitive Athletic Season. *Clinical Journal of Sport Medicine, 23*(4), 312-317.
- Butler, B. W., Lanthier, J., & Wertheimer, S. J. (1993). Subluxing peroneals: a review of the literature and case report. *Journal of Foot and Ankle Surgery, 32*(2), 134-139.

- Carcia, C. R., Martin, R. L., & Drouin, J. M. (2008). Validity of the Foot and Ankle Ability Measure in athletes with chronic ankle instability. *Journal of Athletic Training, 43*(2), 179-183.
- Cárdenas Sandoval, R. P., Garzón-Alvarado, D. A., & Ramírez Martínez, A. M. (2012). A mathematical model of the process of ligament repair: Effect of cold therapy and mechanical stress. *Journal of Theoretical Biology, 302*(0), 53-61.
- Celinder, D., & Peoples, H. (2012). Stroke patients' experiences with Wii Sports® during inpatient rehabilitation. *Scandinavian Journal of Occupational Therapy, 19*(5), 457-463.
- Chang, Y.-J., Chen, S.-F., & Huang, J.-D. (2011). A Kinect-based system for physical rehabilitation: A pilot study for young adults with motor disabilities. *Research in Developmental Disabilities, 32*(6), 2566-2570.
- Chinn, L., & Hertel, J. (2010). Rehabilitation of Ankle and Foot Injuries in Athletes. *Clinics in Sports Medicine, 29*(1), 157-167.
- Clement, D., Granquist, M. D., & Arvinen-Barrow, M. M. (2013). Psychosocial Aspects of Athletic Injuries as Perceived by Athletic Trainers. *Journal of Athletic Training, 48*(4), 512-521.
- Clement, D., Hamson-Utley, J., Arvinen-Barrow, M., Kamphoff, C., Zakrajsek, R. A., & Martin, S. B. (2012). College Athletes' Expectations About Injury Rehabilitation With an Athletic Trainer. *International Journal of Athletic Therapy & Training, 17*(4), 18-27.
- Collado, H., Coudreuse, J. M., Graziani, F., Bensoussan, L., Viton, J. M., & Delarque, A. (2010). Eccentric reinforcement of the ankle evertor muscles after lateral ankle sprain. *Scandinavian Journal of Medicine & Science in Sports, 20*(2), 241-246.
- Connolly, F. R., Aitken, L. M., Tower, M., Connolly, F. R., Aitken, L. M., & Tower, M. (2014). An integrative review of self-efficacy and patient recovery post acute injury. *Journal of advanced nursing, 70*(4), 714.
- Coyne, C. (2008). Video "games" in the clinic: PTs report early results. *PT: Magazine of Physical Therapy, 16*(5), 22-28.
- Cronkey, J., & LaPorta, G. (2012). Rating systems for evaluation of functional ankle instability: prospective evaluation in a cohort of patients treated with monopolar capacitive-coupled radiofrequency. *Foot Ankle Spec, 5*(5), 293-299.
- Denegar, C. R., & Miller, S. J., 3rd. (2002). Can Chronic Ankle Instability Be Prevented? Rethinking Management of Lateral Ankle Sprains. *Journal of Athletic Training, 37*(4), 430-435.
- Docherty, C. L., Valovich McLeod, T. C., & Shultz, S. J. (2006). Postural control deficits in participants with functional ankle instability as measured by the balance error scoring system. *Clinical Journal of Sport Medicine, 16*(3), 203-208.
- Donahue, M., Simon, J., & Docherty, C. L. (2011). Critical review of self-reported functional ankle instability measures. *Foot & Ankle International, 32*(12), 1140-1146.
- Earl, J. E., & Hertel, J. (2001). Lower-extremity muscle activation during the Star Excursion Balance Tests. *Journal of Sport Rehabilitation, 10*(2), 93-104.

- Emery, C. A., & Meeuwisse, W. H. (2010). *The effectiveness of a neuromuscular prevention strategy to reduce injuries in youth soccer: a cluster-randomised controlled trial*. *British Journal of Sports Medicine*, 44(8), 555-562.
- Evans, L., Hardy, L., & Fleming, S. (2000). *Intervention strategies with injured athletes: an action research study*. *Sport Psychologist*, 14(2), 188-206.
- Fernandez-Baena, A., Susin, A., & Lligadas, X. (2012, 19-21 Sept. 2012). *Biomechanical validation of upper-body and lower-body joint movements of Kinect motion capture data for rehabilitation treatments*. Paper presented at the 4th International Conference on Intelligent Networking and Collaborative Systems (INCoS).
- Finch, C., Valuri, G., & Ozanne-Smith, J. (1998). *Sport and active recreation injuries in Australia: evidence from emergency department presentations*. *Br J Sports Med*, 32(3), 220-225.
- Finnoff, J. T., Peterson, V. J., Hollman, J. H., & Smith, J. (2009). *Intrarater and Interrater Reliability of the Balance Error Scoring System (BESS)*. *Physical Medicine & Rehabilitation*, 1(1), 50-54.
- Fitzgerald, D., Trakarnratanakul, N., Smyth, B., & Caulfield, B. (2010). *Effects of a wobble board-based therapeutic exergaming system for balance training on dynamic postural stability and intrinsic motivation levels*. *Journal of Orthopaedic & Sports Physical Therapy*, 40(1), 9.
- Fong, D. T.-P., Hong, Y., Lap-Ki, C., Yung, P. S.-H., & Kai-Ming, C. (2007). *A Systematic Review on Ankle Injury and Ankle Sprain in Sports*. *Sports Medicine*, 37(1), 73-94.
- Fousekis, K., Tsepis, E., & Vagenas, G. (2012). *Intrinsic Risk Factors of Noncontact Ankle Sprains in Soccer: A Prospective Study on 100 Professional Players*. *The American Journal of Sports Medicine*, 40(8), 1842-1850.
- Fung, V., Ho, A., Shaffer, J., Chung, E., & Gomez, M. (2012). *Use of Nintendo Wii Fit in the rehabilitation of outpatients following total knee replacement: A preliminary randomised controlled trial*. *Physiotherapy*, 98(3), 6.
- Garn, A. C., Baker, B. L., Beasley, E. K., & Solmon, M. A. (2012). *What are the benefits of a commercial exergaming platform for college students? Examining physical activity, enjoyment, and future intentions*. *Journal of Physical Activity & Health*, 9(2), 311-318.
- Glazer, D. D. (2009). *Development and Preliminary Validation of the Injury-Psychological Readiness to Return to Sport (I-PRRS) Scale*. *Journal of Athletic Training*, 44(2), 185-189.
- Granito Jr, V. J. (2001). *Athletic injury experience: a qualitative focus group approach*. *Journal of Sport Behavior*, 24(1), 63-82.
- Granquist, M. D., & Brewer, B. W. (2013). *Psychological aspects of rehabilitation adherence*. In M. Arvinen-Barrow & N. Walker (Eds.), *The Psychology of Sport Injury and Rehabilitation* (pp. 40-53). New York, NY: Routledge.

- Granquist, M. D., Gill, D. L., & Appaneal, R. N. (2010). Development of a Measure of Rehabilitation Adherence for Athletic Training. *Journal of Sport Rehabilitation, 19*(3), 249-267.
- Granquist, M. D., Podlog, L., Engel, J. R., & Newland, A. (2014). Certified athletic trainers' perspectives on rehabilitation adherence in collegiate athletic training settings. *Journal of Sports Rehabilitation, 23*(2), 123-133.
- Gribble, P. A., Hertel, J., & Plisky, P. (2012). Using the Star Excursion Balance Test to Assess Dynamic Postural-Control Deficits and Outcomes in Lower Extremity Injury: A Literature and Systematic Review. *Journal of Athletic Training, 47*(3), 339-357.
- Gupta, S. (2011). Intention-to-treat concept: A review. *Perspectives in Clinical Research, 2*(3), 109-112.
- Hale, S. A., Fergus, A., Axmacher, R., & Kiser, K. (2014). Bilateral Improvements in Lower Extremity Function After Unilateral Balance Training in Individuals With Chronic Ankle Instability. *Journal of Athletic Training, 49*(2), 181-191.
- Hale, S. A., & Hertel, J. (2005). Reliability and Sensitivity of the Foot and Ankle Disability Index in Subjects With Chronic Ankle Instability. *Journal of Athletic Training, 40*(1), 35-40.
- Hale, S. A., Hertel, J., & Olmsted-Kramer, L. C. (2007). The effect of a 4-week comprehensive rehabilitation program on postural control and lower extremity function in individuals with chronic ankle instability. *J Orthop Sports Phys Ther, 37*(6), 303-311.
- Han, K., & Ricard, M. D. (2011). Effects of 4 Weeks of Elastic-Resistance Training on Ankle-Evertor Strength and Latency. *Journal of Sport Rehabilitation, 20*(2), 157-173.
- Hertel, J. (2002). Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. *Journal of Athletic Training, 37*(4), 12.
- Hertel, J., & Denegar, C. R. (1998). A rehabilitation paradigm for restoring neuromuscular control following athletic injury. *Athletic Therapy Today, 3*(5), 12-16.
- Hiller, C. E., Kilbreath, S. L., & Refshauge, K. M. (2011). Chronic Ankle Instability: Evolution of the Model. *Journal of Athletic Training, 46*(2), 133-141.
- Hiller, C. E., Refshauge, K. M., Bundy, A. C., Herbert, R. D., & Kilbreath, S. L. (2006). The Cumberland Ankle Instability Tool: A Report of Validity and Reliability Testing. *Archives of Physical Medicine and Rehabilitation, 87*(9), 1235-1241.
- Hintermann, B., Boss, A., & Schäfer, D. (2002). Arthroscopic Findings in Patients with Chronic Ankle Instability. *The American Journal of Sports Medicine, 30*(3), 402-409.
- Holme, E., Magnusson, S. P., Becher, K., Bieler, T., Aagaard, P., & Kjaer, M. (1999). The effect of supervised rehabilitation on strength, postural sway, position sense and re-injury risk after acute ankle ligament sprain. *Scandinavian Journal of Medicine & Science in Sports, 9*(2), 104-109.

- Hootman, J. M., Dick, R., & Agel, J. (2007). *Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. Journal of Athletic Training, 42*(2), 311.
- Hsu, J. K., Thibodeau, R., Wong, S. J., Zukiwsky, D., Cecile, S., & Walton, D. M. (2011). A "Wii" bit of fun: The effects of adding Nintendo Wii<sup>®</sup> Bowling to a standard exercise regimen for residents of long-term care with upper extremity dysfunction. *Physiotherapy Theory & Practice, 27*(3), 185-193.
- Hubbard, T. J., & Denegar, C. R. (2004). Does cryotherapy improve outcomes with soft tissue injury? *Journal of Athletic Training, 39*(3), 278-279.
- Hunt, T. N., Ferrara, M. S., Bornstein, R. A., & Baumgartner, T. A. (2009). The reliability of the modified Balance Error Scoring System. *Clinical Journal of Sport Medicine, 19*(6), 471-475.
- Johnston, E. C., & Howell, S. J. (1999). Tension neuropathy of the superficial peroneal nerve: associated conditions and results of release. *Foot & Ankle International, 20*(9), 576-582.
- Kamphoff, C., Thomae, J., & Hamson-Utley, J. (2013). Integrating the psychological and physiological aspects of sport injury rehabilitation. In M. Arvinen-Barrow & N. Walker (Eds.), *The Psychology of Sport Injury and Rehabilitation* (pp. 134-155). New York, NY: Routledge.
- Karlsson, J., Bergsten, T., Lansinger, O., & Peterson, L. (1988). Reconstruction of the lateral ligaments of the ankle for chronic lateral instability. *The Journal of Bone & Joint Surgery, 70*(4), 581-588.
- Karlsson, J., & Wiger, P. (2002). Longitudinal Split of the Peroneus Brevis Tendon and Lateral Ankle Instability: Treatment of Concomitant Lesions. *Journal of Athletic Training, 37*(4), 463-466.
- Kerkhoffs, G. M., van den Bekerom, M., Elders, L. A., van Beek, P. A., Hullegie, W. A., Bloemers, G. M., . . . de Bie, R. A. (2012). Diagnosis, treatment and prevention of ankle sprains: an evidence-based clinical guideline. *British Journal of Sports Medicine, 46*(12), 854-860.
- Kiers, H., Brumagne, S., Dieën, J., Wees, P., & Vanhees, L. (2012). Ankle proprioception is not targeted by exercises on an unstable surface. *European Journal of Applied Physiology, 112*(4), 1577-1585.
- Kliem, A., & Wiemeyer, J. (2010). Comparison of a traditional and a video game based balance training program. *International Journal of Computer Science in Sport, 9*, 13.
- Knowles, S. B., Marshall, S. W., Miller, T., Spicer, R., Bowling, J. M., Loomis, D., . . . Mueller, F. O. (2007). Cost of injuries from a prospective cohort study of North Carolina high school athletes. *Injury Prevention, 13*(6), 416-421.
- Kristianslund, E., Bahr, R., & Krosshaug, T. (2011). Kinematics and kinetics of an accidental lateral ankle sprain. *Journal of Biomechanics, 44*(14), 2576-2578.

- Lan, M. F., Lane, A. M., Roy, J., & Hanin, N. A. (2012). Validity of the Brunel Mood Scale for use with Malaysian athletes. *Journal of Sports Science & Medicine*, 11(1), 131-135.
- Levy, A. R., Polman, R. C. J., Clough, P. J., & McNaughton, L. R. (2006). Adherence to Sport Injury Rehabilitation Programmes: A Conceptual Review. *Research in Sports Medicine*, 14(2), 149-162.
- Maffulli, N., Ferran, N. A., Oliva, F., & Testa, V. (2006). Recurrent Subluxation of the Peroneal Tendons. *The American Journal of Sports Medicine*, 34(6), 986-992.
- Martin, R. L., Irrgang, J. J., Burdett, R. G., Conti, S. F., & Van Swearingen, J. M. (2005). Evidence of validity for the Foot and Ankle Ability Measure (FAAM). *Foot & Ankle International*, 26(11), 968-983.
- Matharu, G. S., Najran, P. S., & Porter, K. M. (2010). Soft-tissue ankle injuries. *Trauma*, 12(2), 11.
- McGuine, T. A., Brooks, A., & Hetzel, S. (2011). The Effect of Lace-up Ankle Braces on Injury Rates in High School Basketball Players. *The American Journal of Sports Medicine*, 39(9), 1840-1848.
- McGuine, T. A., Hetzel, S., Wilson, J., & Brooks, A. (2012). The Effect of Lace-up Ankle Braces on Injury Rates in High School Football Players. *The American Journal of Sports Medicine*, 40(1), 49-57.
- McKay, G. D., Goldie, P. A., Payne, W. R., & Oakes, B. W. (2001). Ankle injuries in basketball: injury rate and risk factors. *British Journal of Sports Medicine*, 35(2), 103-108.
- McKeon, P. O., & Hertel, J. (2008). Systematic review of postural control and lateral ankle instability, part II: is balance training clinically effective? *Journal of Athletic Training*, 43(3), 305-315.
- McKeon, P. O., Ingersoll, C. D., Kerrigan, D. C., Saliba, E., Bennett, B. C., & Hertel, J. (2008). Balance training improves function and postural control in those with chronic ankle instability. *Medicine & Science in Sports & Exercise*, 40(10), 1810-1819.
- McLeod, T. C. V., Armstrong, T., Miller, M., & Sauers, J. L. (2009). Balance Improvements in Female High School Basketball Players After a 6-Week Neuromuscular-Training Program. *Journal of Sport Rehabilitation*, 18(4), 465-481.
- Meldrum, D., Herdman, S., Moloney, R., Murray, D., Duffy, D., Malone, K., . . . McConn-Walsh, R. (2012). Effectiveness of conventional versus virtual reality based vestibular rehabilitation in the treatment of dizziness, gait and balance impairment in adults with unilateral peripheral vestibular loss: A randomised controlled trial. *BMC Ear, Nose & Throat Disorders*, 12(3), 9.
- Michelson, J., & Hutchins, C. (1995). Mechanoreceptors in human ankle ligaments. *Journal of Bone & Joint Surgery, British Volume*, 77-B(2), 219-224.
- Mickey, L. D. (2012). Therapists say patients' balance and motion improve with help of Wii golf, *The New York Times*.

- Middlemas, D. A., Basilicato, J., Prybicien, M., Savoia, J., & Biodoglio, J. (2009). Incorporating gaming technology into athletic injury rehabilitation. *Athletic Training & Sports Health Care: The Journal for the Practicing Clinician*, 1(2), 79-84.
- O'Driscoll, J., Kerin, F., & Delahunt, E. (2011). Effect of a 6-week dynamic neuromuscular training programme on ankle joint function: A Case report. *SMARTT: Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology*, 3(1), 13-19.
- O'Neill, P. J., Parks, B. G., Walsh, R., Simmons, L. M., & Miller, S. D. (2007). Excursion and Strain of the Superficial Peroneal Nerve During Inversion Ankle Sprain. *The Journal of Bone & Joint Surgery*, 89(5), 979-986.
- Pasch, M., Bianchi-Berthouze, N., van Dijk, B., & Nijholt, A. (2009). Movement-based sports video games: Investigating motivation and gaming experience. *Entertainment Computing*, 1(2), 49-61.
- Powers, M. E., Buckley, B. D., Kaminski, T. W., Hubbard, T. J., & Ortiz, C. (2004). Six Weeks of Strength and Proprioception Training Does Not Affect Muscle Fatigue and Static Balance in Functional Ankle Instability. *Journal of Sport Rehabilitation*, 13(3), 201-227.
- Renström, P. A., & Konradsen, L. (1997). Ankle ligament injuries. *British Journal of Sports Medicine*, 31(1), 11-20.
- Riemann, B. L., Guskiewicz, K. M., & Shields, E. W. (1999). Relationship between clinical and forceplate measures of postural stability. *Journal of Sport Rehabilitation*, 8(2), 71-82.
- Roth, J. A. (2010). Peroneal tendon subluxation: the other lateral ankle injury. *British Journal of Sports Medicine*, 44(14), 1047-1053.
- Saini, S., Rambli, D. R. A., Sulaiman, S., Zakaria, M. N., & Shukri, S. R. M. (2012, 12-14 June 2012). A low-cost game framework for a home-based stroke rehabilitation system. Paper presented at the 2012 International Conference on Computer & Information Science (ICIS).
- Schaefer, J. L., & Sandrey, M. A. (2012). Effects of a 4-Week Dynamic-Balance-Training Program Supplemented With Graston Instrument-Assisted Soft-Tissue Mobilization for Chronic Ankle Instability. *Journal of Sport Rehabilitation*, 21(4), 313-326.
- Sims, J., Cosby, N., Saliba, E. N., Hertel, J., & Saliba, S. A. (2013). Exergaming and Static Postural Control in Individuals With a History of Lower Limb Injury. *Journal of Athletic Training*, 48(3), 314-325.
- Sluijs, E. M., Kok, G. J., & van der Zee, J. (1993). Correlates of Exercise Compliance in Physical Therapy. *Physical Therapy*, 73(11), 771-782.
- Taga, I., Shino, K., Inoue, M., Nakata, K., & Maeda, A. (1993). Articular cartilage lesions in ankles with lateral ligament injury. An arthroscopic study. *The American Journal of Sports Medicine*, 21(1), 120-126; discussion 126-127.

- Takao, M., Miyamoto, W., Matsui, K., Sasahara, J., & Matsushita, T. (2012). *Functional Treatment After Surgical Repair for Acute Lateral Ligament Disruption of the Ankle in Athletes*. *The American Journal of Sports Medicine*, 40(2), 447-451.
- Taylor, A. H., & May, S. (1996). *Threat and coping appraisal as determinants of compliance with sports injury rehabilitation: an application of Protection Motivation Theory*. *J Sports Sci*, 14(6), 471-482.
- Terry, P. C., & Lane, A. M. (2010). *User Guide for the Brunel Mood Scale (BRUMS)*, University of Wolverhampton, UK.
- Terry, P. C., Lane, A. M., & Fogarty, G. J. (2003). *Construct validity of the Profile of Mood States – Adolescents for use with adults*. *Psychology of Sport and Exercise*, 4(2), 125-139.
- Tracey, J. (2003). *The emotional response to the injury and rehabilitation process*. *Journal of Applied Sport Psychology*, 15(4), 279-293.
- Uitenbroek, D. G. (1996). *Sports, exercise, and other causes of injuries: results of a population survey*. *Res Q Exerc Sport*, 67(4), 380-385.
- van den Hoogen, W., Ijsselsteijn, W., & de Kort, Y. (2009, June 29 2009-July 2 2009). *Yes Wii can! Using digital games as a rehabilitation platform after stroke - The role of social support*. Paper presented at the Virtual Rehabilitation International Conference, 2009.
- van der Wees, P. J., Lenssen, A. F., Hendriks, E. J., Stomp, D. J., Dekker, J., & de Bie, R. A. (2006). *Effectiveness of exercise therapy and manual mobilisation in ankle sprain and functional instability: a systematic review*. *Australian Journal of Physiotherapy*, 52(1), 27-37.
- Vernadakis, N., Derri, V., Tsitskari, E., & Antoniou, P. (2014). *The effect of Xbox Kinect intervention on balance ability for previously injured young competitive male athletes: A preliminary study*. *Physical Therapy in Sport*, 15(3), 148-155.
- Walker, N., & Heaney, C. (2013). *Psychological responses to injury*. In M. Arvinen-Barrow & N. Walker (Eds.), *The Psychology of Sport Injury and Rehabilitation* (pp. 23-39). New York, NY: Routledge.
- Wall, E., Massie, J., Kwan, M., Rydevik, B., Myers, R., & Garfin. (1992). *Experimental stretch neuropathy. Changes in nerve conduction under tension*. *Journal of Bone & Joint Surgery, British Volume*, 74-B(1), 126-129.
- Wiese-bjornstal, D. M., Smith, A. M., Shaffer, S. M., & Morrey, M. A. (1998). *An integrated model of response to sport injury: Psychological and sociological dynamics*. *Journal of Applied Sport Psychology*, 10(1), 46-69.
- Wiese, D. M., & Weiss, M. R. (1987). *Psychological Rehabilitation and Physical Injury: Implications for the Sportsmedicine Team*. *Sport Psychologist*, 1(4), 318-330.
- Williams, J. M., & Andersen, M. B. (1998). *Psychosocial antecedents to sports injury: Review and critique of the Stress and Injury model*. *Journal of Applied Sport Psychology*, 10, 21.



- Witchalls, J., Blanch, P., Waddington, G., & Adams, R. (2012). *Intrinsic functional deficits associated with increased risk of ankle injuries: a systematic review with meta-analysis*. *British Journal of Sports Medicine*, 46(7), 515-523.
- Yang, J., Tibbetts, A. S., Covassin, T., Cheng, G., Nayar, S., & Heiden, E. (2012). *Epidemiology of Overuse and Acute Injuries Among Competitive Collegiate Athletes*. *Journal of Athletic Training*, 47(2), 198-204.
- Zech, A., Klahn, P., Hoefl, J., Eulenburger, C., Steib, S., Zech, A., . . . Steib, S. (2014). *Time course and dimensions of postural control changes following neuromuscular training in youth field hockey athletes*. *European Journal of Applied Physiology*, 114(2), 395-403.
- Zöch, C., Fialka-Moser, V., & Quittan, M. (2003). *Rehabilitation of ligamentous ankle injuries: a review of recent studies*. *British Journal of Sports Medicine*, 37(4), 291-295.

***Appendix A:***  
Cumberland Ankle Instability Tool

**Cumberland Ankle Instability Tool (CAIT)**

For each question, select the answer that BEST describes your ankle.

---

**I have pain in my ankle**

- Never
  - During sport
  - When I run on uneven surfaces
  - When I run on level surfaces
  - When I walk on uneven surfaces
  - When I walk on level surfaces
- 

**My ankle feels UNSTABLE**

- Never
  - Sometimes during sport (not every time)
  - Frequently during sport (every time)
  - Sometimes during daily activity
  - Frequently during daily activity
- 

**When I make SHARP turns, my ankle feel UNSTABLE**

- Never
  - Sometimes when running
  - Often when running
  - When walking
- 

**When going down the stairs, my ankle feels UNSTABLE**

- Never
  - If I go fast
  - Occasionally
  - Always
- 

**My ankle feels UNSTABLE when standing on one leg**

- Never
- On the ball of my foot
- With my foot flat

**My ankle feels UNSTABLE when**

- Never
  - When I hop from side to side
  - When I hop on a spot
  - When I jump
- 

**My ankle feels UNSTABLE when**

- Never
  - I run on uneven surfaces
  - I jog on uneven surfaces
  - I walk on uneven surfaces
  - I walk on flat surfaces
- 

**TYPICALLY, when I start to roll over (or "twist") on my ankle, I can stop it**

- Immediately
  - Often
  - Sometimes
  - Never
  - I have never rolled over on my ankle
- 

**After a TYPICAL incident of my ankle rolling over, my ankle returns to normal**

- Almost immediately
  - Less than one day
  - 1-2 days
  - More than 2 days
  - I have never rolled over on my ankle
- 
-

***Appendix B:***

Injury-Psychological Readiness to Return to Sport Scale

Please answer each item on a scale of 0 (No confidence at all) to 10 (Complete confidence)	
1. Overall confidence to play	
2. Confidence to play without pain	
3. Confidence to give 100% effort	
4. Confidence in injured body part to handle the demands of the situation	
5. Confidence in skill level/ability	
6. Confidence to not concentrate on the injury	

***Appendix C:***  
Brunel Mood Scale

## The Brunel Mood Scale

Name: \_\_\_\_\_ Age: \_\_\_\_\_ Gender: M / F Date: / /

Below is a list of words that describe feelings. Please read each one carefully. Then mark the box that best describes HOW YOU FEEL RIGHT NOW. Make sure you answer every question.

		Not at all	A little	Moderately	Quite a bit	Extremely
1. Panicky .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Lively .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Confused .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Worn out .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Depressed .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Downhearted .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Annoyed .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. Exhausted .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Mixed-up .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. Sleepy .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. Bitter .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12. Unhappy .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13. Anxious .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14. Worried .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15. Energetic .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16. Miserable .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17. Muddled .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18. Nervous .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19. Angry .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20. Active .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21. Tired .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22. Bad tempered .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23. Alert .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24. Uncertain .....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

For official use only:

Ang: \_\_\_\_\_ Con: \_\_\_\_\_ Dep: \_\_\_\_\_ Fat: \_\_\_\_\_ Ten: \_\_\_\_\_ Vig: \_\_\_\_\_



***Appendix D:***

Rehabilitation Adherence Measure for Athletic Training

Please rate the athlete on each item using the scale: 1= <i>never</i> , 2= <i>occasionally</i> , 3= <i>often</i> , 4= <i>always</i>				
1. Attends scheduled rehabilitation sessions	1	2	3	4
2. Arrives at rehabilitation on time	1	2	3	4
3. Follows the athletic trainer's instructions during rehabilitation sessions	1	2	3	4
4. Follows the prescribed rehabilitation plan	1	2	3	4
5. Completes all tasks assigned by the athletic trainer	1	2	3	4
6. Asks questions about his or her rehabilitation	1	2	3	4
7. Communicates with the athletic trainer if there is a problem with the exercises	1	2	3	4
8. Provides the athletic trainer feedback about the rehabilitation program	1	2	3	4
9. Has a positive attitude during rehabilitation sessions	1	2	3	4
10. Has a positive attitude toward the rehabilitation process	1	2	3	4
11. Gives 100% effort in rehabilitation sessions	1	2	3	4
12. Is self-motivated in rehabilitation sessions	1	2	3	4
13. Is an active participant in the rehabilitation process	1	2	3	4
14. Stays focused while doing rehabilitation exercises	1	2	3	4
15. Is motivated to complete rehabilitation	1	2	3	4
16. Shows interest in the rehabilitation process	1	2	3	4

***Appendix E:***

Foot and Ankle Ability Measure

Please answer every question with <b>one</b> response that most closely describes your condition within the past week. If the activity in question is limited by something other than your foot or ankle mark "Not Applicable" (N/A).						
Because of your foot and ankle how much difficulty do you have with:	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
<b>Standing</b>						
<b>Walking on even ground</b>						
<b>Walking on even ground without shoes</b>						
<b>Walking up hills</b>						
<b>Walking down hills</b>						
<b>Going up stairs</b>						
<b>Going down stairs</b>						
<b>Walking on uneven ground</b>						
<b>Stepping up and down curbs</b>						
<b>Squatting</b>						
<b>Coming up on your toes</b>						
<b>Walking initially</b>						
<b>Walking 5 minutes or less</b>						
<b>Walking approximately 10 minutes</b>						
<b>Walking 15 minutes or greater</b>						
<b>Home responsibilities</b>						
<b>Activities of daily living</b>						
<b>Personal care</b>						
<b>Light to moderate work (standing, walking)</b>						
<b>Heavy work (push/pulling, climbing, carrying)</b>						
<b>Recreational activities</b>						

***Appendix F:***

Foot and Ankle Ability Measure – Sport

Please answer every question with <b>one</b> response that most closely describes your condition within the past week. If the activity in question is limited by something other than your foot or ankle mark "Not Applicable" (N/A).						
Because of your foot and ankle how much difficulty do you have with:	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
<b>Running</b>						
<b>Jumping</b>						
<b>Landing</b>						
<b>Starting and stopping quickly</b>						
<b>Cutting/lateral movements</b>						
<b>Low impact activities</b>						
<b>Ability to perform activity with your normal technique</b>						
<b>Ability to participate in your desired sport as long as you like</b>						

***Appendix G:***

Frequency tables for CAI participant demographics

**Gender**

	AVG Frequency	Percent	Trad Frequency	Percent
F	6	60.0	3	30.0
M	4	40.0	7	70.0
Total	10	100.0	10	100.0

**Involved Side**

	AVG Frequency	Percent	Trad Frequency	Percent
L	5	50.0	5	50.0
R	5	50.0	5	50.0
Total	10	100.0	10	100.0

**Last Sprain**

	AVG Frequency	Percent	Trad Frequency	Percent
2-4 weeks	4	40.0	1	10.0
3-6 months	1	10.0	5	50.0
>6 months	5	50.0	4	40.0
Total	10	100.0	10	100.0



**Number of Sprains**

	AVG Frequency	Percent	Trad Frequency	Percent
Once	0	0.0	3	30.0
Twice	3	30.0	2	20.0
Three times	3	30.0	2	20.0
> 3 times	4	40.0	3	30.0
Total	10	100.0	10	100.0

**ATF Laxity**

	AVG Frequency	Percent	Trad Frequency	Percent
Grade 1	2	20.0	4	40.0
Grade 2	2	20.0	2	20.0
None	6	60.0	4	40.0
Total	10	100.0	10	100.0

**CF Laxity**

	AVG Frequency	Percent	Trad Frequency	Percent
Grade 1	2	20.0	1	10.0
None	8	80.0	9	90.0
Total	10	100.0	10	100.0

**Completed Rehab Program Previously**

	AVG Frequency	Percent	Trad Frequency	Percent
Not at all	4	40.0	5	50.0
Partially	3	30.0	4	40.0
Yes	3	30.0	1	10.0
Total	10	100.0	10	100.0

**Amount of experience playing Nintendo Wii™**

	AVG Frequency	Percent	Trad Frequency	Percent
<5 times	1	10.0	2	20.0
5-10 times	4	40.0	4	40.0
10-20 times	1	10.0	1	10.0
>20 times	3	30.0	2	20.0
Never	1	10.0	1	10.0
Total	10	100.0	10	100.0

**Amount of experience playing Xbox Kinect™**

	AVG Frequency	Percent	Trad Frequency	Percent
<5 times	1	10.0	1	10.0
5-10 times	2	20.0	3	30.0
10-20 times	0	0.0	0	0.0
>20 times	2	20.0	1	10.0
Never	5	50.0	5	50.0
Total	10	100.0	10	100.0

**Level of enjoyment playing AVG**

	AVG Frequency	Percent	Trad Frequency	Percent
Delightful	2	20.0	1	10.0
Excellent	1	10.0	1	10.0
Satisfactory	6	60.0	4	40.0
Unsatisfactory	0	0.0	1	10.0
Miserable	0	0.0	1	10.0
N/A	1	10.0	2	20.0
Total	10	100.0	10	100.0

***Appendix H:***

Values for each data point of LAS condition's I-PRRS, RAdMAT, FAAM and FAAMS.

## AVG Participant

Measure	Injury baseline	Start of Strength Phase	Start of Balance Phase	Return to Play	Post setback Baseline	Balance Training Baseline	Week 2 Balance Training	End Balance Training
I-PRRS	0	5	30	39	31	12	47	50
RAdMAT	59	55	54	54	57	54	Missing	56
FAAM	11.9%	58.3%	79.8%	Missing	Missing	59.5%	85.7%	80.9%
FAAMS	0%	28.1%	56.3%	Missing	Missing	21.9%	59.4%	62.5%

## Traditional Participant

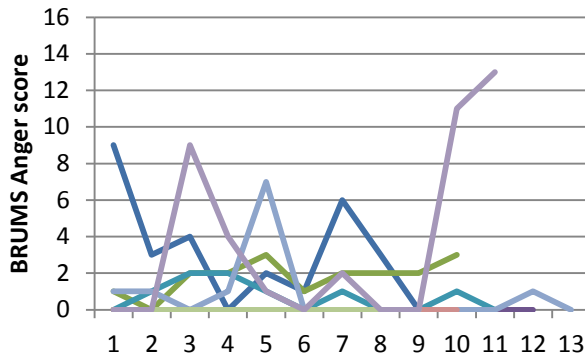
Measure	Injury Baseline	Start of Strength & Balance Phase & Return to Play	Week 2 Balance Training	End Balance Training
I-PRRS	5	15	37	55
RAdMAT	50	48	45	46
FAAM	56.0%	75.0%	97.6%	98.8%
FAAMS	9.4%	40.6%	84.4%	93.8%

***Appendix I:***

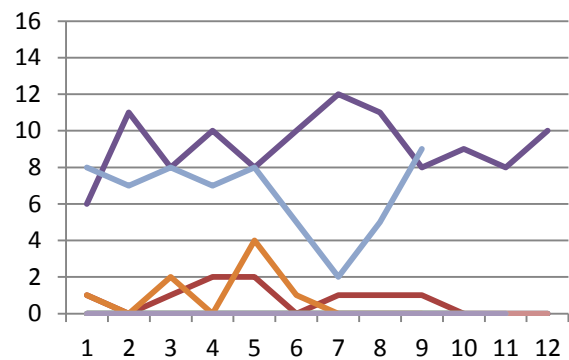
Individual BRUMS results for CAI groups.

Charts which appear to have less than 10 lines indicate participants' scores were at 0.

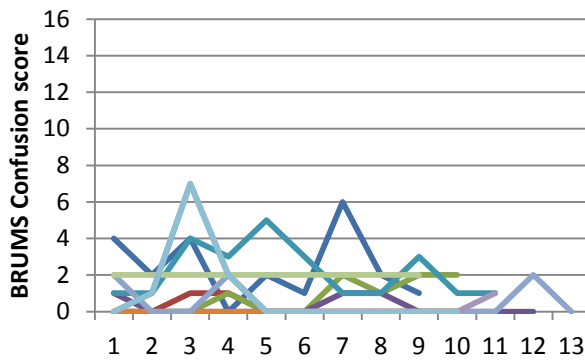
**AVG Anger**



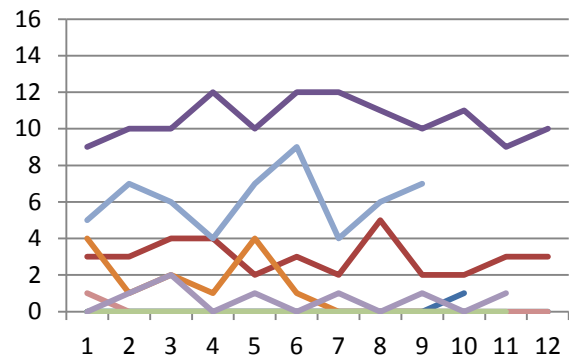
**Trad Anger**



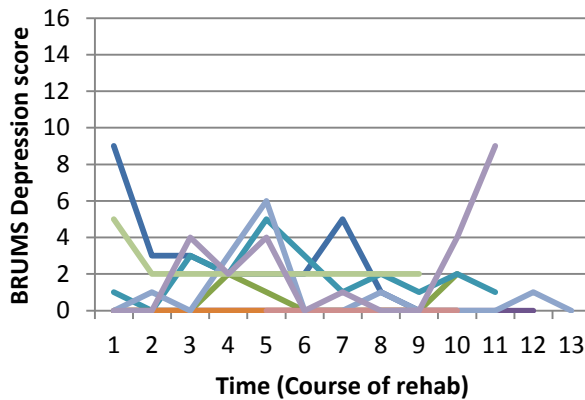
**AVG Confusion**



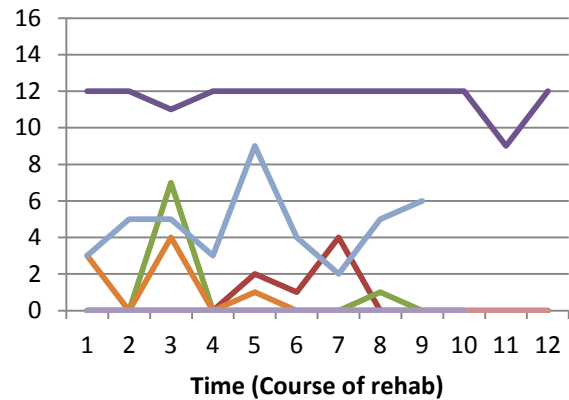
**Trad Confusion**



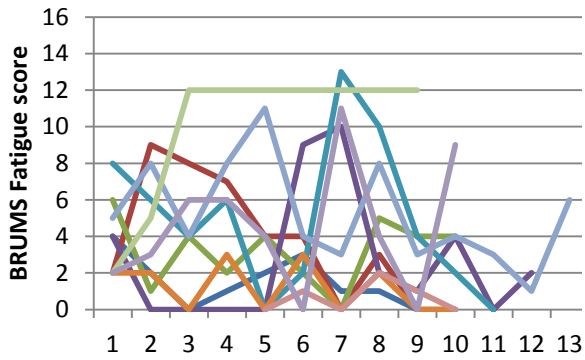
**AVG Depression**



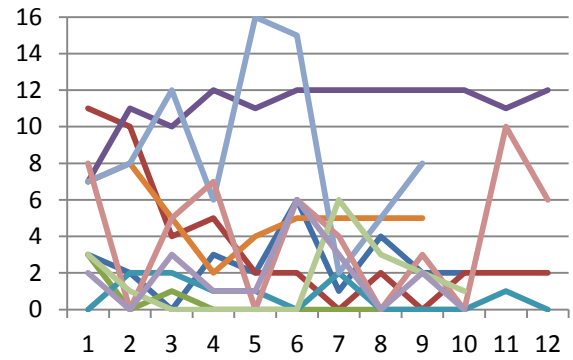
**Trad Depression**



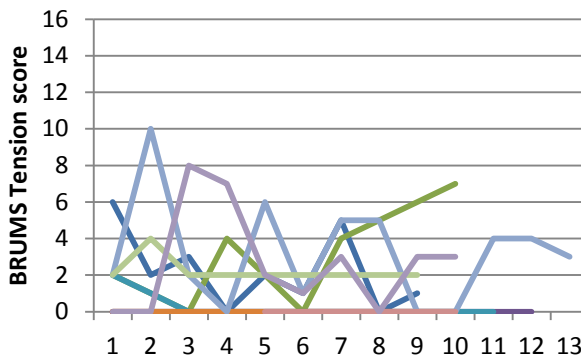
**AVG Fatigue**



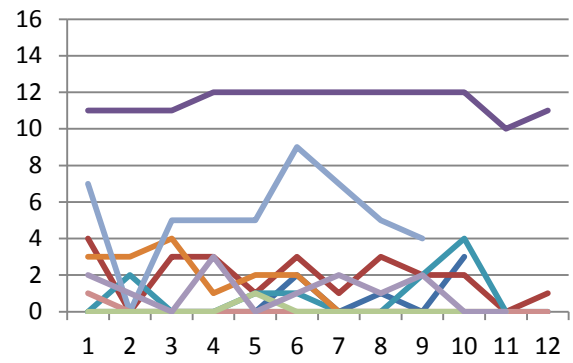
**Trad Fatigue**



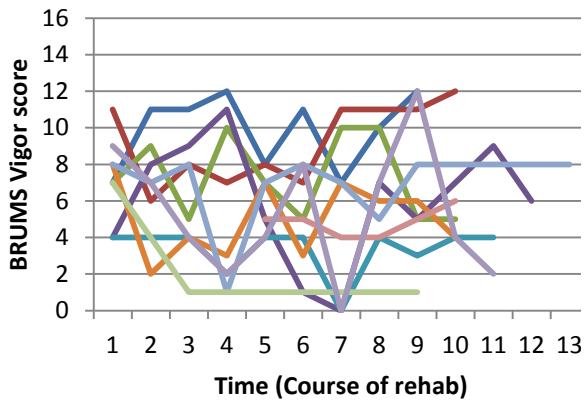
**AVG Tension**



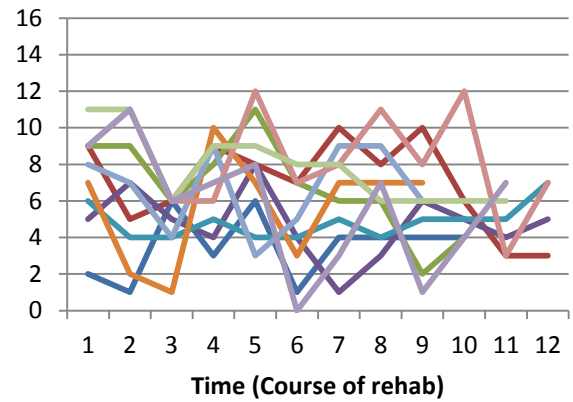
**Trad Tension**



**AVG Vigor**



**Trad Vigor**



***Appendix J:***

Informed consent form.



# UNIVERSITY OF WISCONSIN – MILWAUKEE CONSENT TO PARTICIPATE IN RESEARCH

THIS CONSENT FORM HAS BEEN APPROVED BY THE IRB FOR A ONE YEAR PERIOD

## 1. General Information

**Study title:** Effects of active video gaming on the rehabilitation of lateral ankle sprains

**Person in Charge of Study (Principal Investigator, PI):**

Jennifer E Earl-Boehm, Ph.D, LAT  
Department of Kinesiology

**Student Principal Investigator (SPI):**

Nate Maresh, LAT, ATC  
Master's degree student in the College of Health Sciences

## 2. Study Description

You are being asked to participate in a research study. Your participation is completely voluntary. You do not have to participate if you do not want to.

**Study description:**

The purpose of this study is to look at the differences between doing normal therapy and therapy while playing video games after hurting your ankle. This study is being done to see if patients will respond differently to different therapy programs. We want to see if playing Xbox Kinect games while balancing gives the same benefits as regular balance exercises. The study will be done in the Athletic Training Room (Pavilion or Englemann Hall) where you normally get help for your injury. We expect 30 people who hurt their ankle while playing sports here at UW-Milwaukee, or who have a history of ankle sprains will be able to be in this study. The study will last at least 4 weeks after you are included into the study. Your rehabilitation sessions will last about 30-45 minutes 3-5 days a week and be done around your own personal schedule.

## 3. Study Procedures

**What will I be asked to do if I participate in the study?**

If you agree to participate you will be asked to do ankle therapy in an athletic training room or research laboratory. You will randomly be put into either a group that does normal therapy or therapy with video games. After the ankle injury you will be asked to fill out a survey (1-2 minutes) about how your ankle feels and when your ankle injury happened. You will then be asked to do different exercises depending on what group you are put in. If the ankle injury is recent, both groups will ice (20 minutes at a time, 3 times per day) and do range of motion exercises (5-10 minutes, twice per day). When you can move your ankle without pain you will start ankle strengthening exercises (15-20 minutes per

day) with resistance bands. After you can stand on your injured ankle without pain, or if your injury happened a while ago, you will start balance exercises (15-30 minutes per day). One group will do regular balance exercises on the injured ankle and the other group will balance on the injured ankle while playing games on the Xbox Kinect. The balance exercises will last at least 4 weeks. If you are ready to return to full play in your sport or activity before the end of the 4 weeks you will be allowed to return to play but you will be asked to complete the exercises for the rest of the 4 week period.

Every other day following your therapy session you will be asked to rate your pain and mood on a computer survey. These surveys will take about 2-3 minutes to complete. At different times during the therapy you will also be asked to do a survey about how confident you are to play your sport (1 minute). At the same time your athletic trainer will do a survey about how you behave during your therapy. At the beginning of your 4 week balance exercises you will be asked to complete two balance tests that may take 10-15 minutes. One of these tests will ask you stand on either one or two feet, on flat ground or a foam pad. You will be asked to stand as still as possible for 20 seconds while the PI watches for balance mistakes. The second test will have you stand on one leg and reach with your other leg as far as you can in 3 directions a few times. You will be asked to do these tests again every other week. At the same time as these tests you will be asked to redo the same survey about how your ankle feels that you did right after you hurt your ankle.

You may be photographed or videotaped during this study to make it easier to show others what was done in this study. Your face will not be shown and your voice will not be heard. If you do not want to be photographed or videotaped you may still be in this study. At the end of this form there is a spot where you can say "yes" or "no" to being photographed or videotaped.

#### **4. Risks and Minimizing Risks**

##### **What risks will I face by participating in this study?**

###### **Physical risks:**

There is a risk of re-injuring your ankle however this risk is low and is not expected to be higher than when doing normal therapy for your ankle. You will be in daily contact with your athletic trainer and they will decide when you are ready for the next step in your therapy. They will not allow you to move forward until they feel it is safe for you to do. There is a risk for some soreness in your ankle from the balance exercises in both groups. The group that plays the Xbox Kinect games is also at risk of having mild muscle soreness in your shoulders or hips as well.

###### **Psychosocial risks:**

There are no foreseeable psychological risks for participating in this research study.

## 5. Benefits

### **Will I receive any benefit from my participation in this study?**

There are no known benefits to you other than to further research.

## 6. Study Costs and Compensation

### **Will I be charged anything for participating in this study?**

You will not be responsible for any of the costs from taking part in this research study.

### **Are subjects paid or given anything for being in the study?**

If you are included into the study you will be awarded \$50 in gift cards. If you complete the entire study you will also receive an additional \$50 in gift cards. This will be given out at the completion of the study.

## 7. Confidentiality

### **What happens to the information collected?**

All information collected about you during the course of this study will be kept confidential to the extent permitted by law. We may decide to present what we find to others, or publish our results in scientific journals or at scientific conferences. Only the principal investigator (PI), Dr. Jennifer Earl-Boehm, Dr. Monna Arvinen-Barrow, and the student principal investigator (SPI), Nate Maresh, will have access to the information. However, the Institutional Review Board at UW-Milwaukee or appropriate federal agencies like the Office for Human Research Protections may review this study's records.

All of your information will be coded to protect your identity. Only the PI and SPI will have this code. This code and anything about your identity will be kept in a locked file cabinet in a private office. When the study is done, all identity related information will be destroyed. Test results will be kept to help with future research.

## 8. Alternatives

### **Are there alternatives to participating in the study?**

If you do not wish to participate in this study and you injure your ankle you will receive the normal therapy from your athletic trainer or clinician to whom you were referred.

## 9. Voluntary Participation and Withdrawal

### **What happens if I decide not to be in this study?**

Your participation in this study is entirely voluntary. You may choose not to take part in this study. If you decide to take part, you can change your mind later and withdraw from the study. You are free to not answer any questions or withdraw at any time. Your decision will not change any present or future relationships with the University of Wisconsin Milwaukee. If you decide to withdraw from the study before it is over we will use the information that was collected up the point when you decided to withdraw from the study.

## 10. Questions

### **Who do I contact for questions about this study?**

For more information about the study or the study procedures or treatments, or to withdraw from the study, contact:

Jennifer E. Earl-Boehm, Ph.D., LAT  
Department of Kinesiology  
PO Box 413, Department of Kinesiology, Milwaukee, WI 53201  
414-229-3227

Nate Maresh, LAT, ATC  
Department of Kinesiology  
Pavilion 375  
920-629-0893

### **Who do I contact for questions about my rights or complaints towards my treatment as a research subject?**

The Institutional Review Board may ask your name, but all complaints are kept in confidence.

Institutional Review Board  
Human Research Protection Program  
Department of University Safety and Assurances  
University of Wisconsin – Milwaukee  
P.O. Box 413  
Milwaukee, WI 53201  
(414) 229-3173

## 11. Signatures

### Research Subject's Consent to Participate in Research:

*To voluntarily agree to take part in this study, you must sign on the line below. If you choose to take part in this study, you may withdraw at any time. You are not giving up any of your legal rights by signing this form. Your signature below indicates that you have read or had read to you this entire consent form, including the risks and benefits, and have had all of your questions answered, and that you are 18 years of age or older.*

\_\_\_\_\_  
Printed Name of Subject/ Legally Authorized Representative

\_\_\_\_\_  
Signature of Subject/Legally Authorized Representative

\_\_\_\_\_  
Date

### Research Subject's Consent to Audio/Video/Photo Recording:

It is okay to videotape or photograph me while I am in this study and use my videotaped or photographed data in the research.

Please initial: \_\_\_Yes \_\_\_No

### Principal Investigator (or Designee)

*I have given this research subject information on the study that is accurate and sufficient for the subject to fully understand the nature, risks and benefits of the study.*

\_\_\_\_\_  
Printed Name of Person Obtaining Consent

\_\_\_\_\_  
Study Role

\_\_\_\_\_  
Signature of Person Obtaining Consent

\_\_\_\_\_  
Date

***Appendix K:***  
IRB Manager Protocol Form

## IRBManager Protocol Form

**Instructions:** Each Section must be completed unless directed otherwise. Incomplete forms will delay the IRB review process and may be returned to you. Enter your information in the **colored boxes** or place an **"X"** in front of the appropriate response(s). If the question does not apply, write **"N/A."**

### SECTION A: Title

#### A1. Full Study

Effects of active video gaming on the rehabilitation of lateral ankle sprains

**Title:**

### SECTION B: Study Duration

**B1. What is the expected start date?** *Data collection, screening, recruitment, enrollment, or consenting activities may not begin until IRB approval has been granted. Format: 07/05/2011*

09/23/2013

**B2. What is the expected end date?** *Expected end date should take into account data analysis, queries, and paper write-up. Format: 07/05/2014*

05/21/2014

### SECTION C: Summary

**C1. Write a brief descriptive summary of this study in Layman Terms (non-technical language):**

This study will look at the physical, psychosocial, and patient-oriented outcomes using active video games (AVG) via the Xbox Kinect in the balance training stage in the rehabilitation lateral ankle sprains (LAS) in college-aged subjects. The rate of LAS has remained the same over the past 15 years in spite of continued research into the care and rehabilitation of the injury. After sustaining a LAS, up to 26% of subjects may sustain an additional LAS. This may be due to a lack of adherence to the prescribed rehabilitation following their return to full participation of their sports activities. The use of AVG in rehabilitation of other long term conditions has been proposed to provide similar physical benefits while also having positive effects on a patient's psyche, including enjoyment and increased rehabilitation adherence. This study will compare differences in the physical (balance), psychosocial (confidence to return to play, current mood states, and rehabilitation adherence), and patient-oriented (self-reported ankle function) outcomes between groups of traditional rehabilitation and rehabilitation utilizing AVG during the balance training phase of their rehabilitation. The study will recruit athletes from the University of Wisconsin-Milwaukee sports teams who suffer an acute LAS as well as recreational athletes with a history of LAS or chronic ankle instability (CAI). The study will take place in the athletic training/sports medicine facilities of the Pavilion and Engelmann Hall.

**C2. Describe the purpose/objective and the significance of the research:**

The purpose of this study is to look at the functional, psychosocial, and patient-oriented outcomes of a rehabilitation program including AVG to traditional rehabilitation for the treatment of lateral ankle sprains. To achieve this, we will have 4 specific aims:

- 1) To compare the changes in static and dynamic balance between AVG and traditional rehabilitation protocols,
- 2) To compare the changes in an athletes' cognitive appraisal of ankle sprains upon return to play between AVG and traditional rehabilitation protocols,
- 3) To compare the changes in self-reported ankle function of AVG and traditional rehabilitation protocols, and
- 4) To describe the cognitive (return to play confidence), emotional (mood states), and behavioral (rehabilitation adherence) responses of AVG and traditional rehabilitation patients throughout the rehabilitation process.

Results from this study may give evidence for the application of rehabilitation tool to help clinicians increase rehabilitation adherence. The current study will also add to a limited, but growing, body of literature on the effects of the use of AVG in rehabilitation settings.

**C3. Cite any relevant literature pertaining to the proposed research:**



Lateral ankle sprains (LAS) are an injury to the lateral ankle ligaments following excessive inversion of the foot and ankle, commonly referred to as “rolling” one’s ankle, are common in sports that demand high amounts of cutting, pivoting, and landing.<sup>1</sup> About 11,000 LAS occur annually across all NCAA colleges.<sup>2</sup> Recurrent LAS may develop into the long term disability of chronic ankle instability (CAI).<sup>1</sup> The current standard in care for the rehabilitation of LAS includes ankle strength training, balance training, and sport specific exercises.<sup>3</sup> Exercises within the balance training portion typically contain single leg stance tasks, increasing difficulty by introducing unstable surfaces to stand on, such as foam padding or inflatable platforms.<sup>3</sup> Research into balance training exercises for the rehabilitation of LAS has shown reduction in recurrent LAS by up to 60%.<sup>3</sup> Many injured athletes view LAS as a minor injury which makes long term rehabilitation adherence difficult.<sup>1</sup> One method to improve rehabilitation adherence is to increase the variation of exercises during the rehabilitation protocol.<sup>4</sup> Research into the long term rehabilitation programs in the care for stroke recovery or falls prevention training in the elderly has suggested that the use of AVG may influence some psychological factors, such as enjoyment and rehabilitation adherence, while providing physical benefits in balance that are comparable to traditional rehabilitation.<sup>5</sup> Few of these studies provide measureable evidence for these psychological benefits. Little research on the use of AVG has been performed in musculoskeletal rehabilitation.

#### References:

1. Hertel, J. (2002). "Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability." *Journal of Athletic Training* 37(4): 12.
2. Hootman, J. M., et al. (2007). "Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives." *Journal of Athletic Training* 42(2): 311.
3. McKeon, P. O. and J. Hertel (2008). "Systematic review of postural control and lateral ankle instability, part II: is balance training clinically effective?" *J Athl Train* 43(3): 305-315.
4. Arvinen-Barrow, M., et al. (2007). "Views of Chartered Physiotherapists on the Psychological Content of Their Practice: A Follow-Up Survey in the UK." *Journal of Sport Rehabilitation* 16(2): 111-121.
5. Fitzgerald, D., et al. (2010). "Effects of a wobble board-based therapeutic exergaming system for balance training on dynamic postural stability and intrinsic motivation levels." *Journal of Orthopaedic & Sports Physical Therapy* 40(1): 9.

**Section Notes...**

- D1. If this study involves analysis of de-identified data only (i.e., no human subject interaction), IRB submission/review may not be necessary. Visit the Pre-Submission section in the [IRB website](#) for more information.

**D1. Identify any population(s) that you will be specifically targeting for the study. Check **all** that apply: (Place an "X" in the column next to the name of the special population.)**

	Not Applicable (e.g., de-identified datasets)		Institutionalized/ Nursing home residents recruited in the nursing home
	UWM Students of PI or study staff		Diagnosable Psychological Disorder/Psychiatrically impaired
	Non-UWM students to be recruited in their educational setting, i.e. in class or at school		Decisionally/Cognitively Impaired
	UWM Staff or Faculty		Economically/Educationally Disadvantaged
	Pregnant Women/Neonates		Prisoners
	Minors under 18 and ARE NOT wards of the State		Non-English Speaking
	Minors under 18 and ARE wards of the State		Terminally ill
<b>X</b>	Other (Please identify): Student-athletes of UWM NCAA teams, UWM students with a history of LAS or CAI		

**D2. Describe the subject group and enter the total number to be enrolled for each group.** For example: teachers-50, students-200, parents-25, parent's children-25, student control-30, student experimental-30, medical charts-500, dataset of 1500, etc. Enter the total number of subjects below.

<b>Describe subject group:</b>	<b>Number:</b>
Student-athlete control	5
Student-athlete experimental	5

Student with history of LAS or CAI control	10
Student with history of LAS or CAI experimental	10
<b>TOTAL # OF SUBJECTS:</b>	30
<b>TOTAL # OF SUBJECTS (If UWM is a collaborating site):</b>	

**D3. List any major inclusion and exclusion criteria (e.g., age, gender, health status/condition, ethnicity, location, English speaking, etc.) and state the justification for the inclusion and exclusion:**

Inclusion criteria require sustaining an acute lateral ankle sprain during an athletic practice or competition as a student-athlete at UW-M and are otherwise healthy

-OR-

A UW-M student having had an ankle sprain in the previous 3 months or multiple ankle sprains over the past year and are otherwise healthy.

The definition of an acute lateral ankle sprain utilized for the present study is an injury which is a result of participation in their respective sport, requires absence from practice or competitive participation for >24 hours, and is diagnosed as an ankle sprain by either a licensed athletic trainer or physician.

Exclusion from the study may occur if:

- 1) A fracture of the lower leg, ankle, or foot is present. If a fracture is suspected during evaluation of the injury it must be ruled out by x-ray prior to inclusion.
- 2) The ankle injury also resulted in an injury to the distal tibiofibular ligament or syndesmosis (high ankle sprain),
- 3) Current injury necessitates surgical intervention,
- 4) The athlete is currently pregnant, or
- 5) The athlete suffers from a condition affecting the vestibular system.

**Section Notes...**

- E1. Make sure to attach any recruitment materials for IRB approval.
- E3. The privacy of the participants must be maintained throughout the consent process.

**E1. Describe how the subjects will be recruited.** (E.g., through flyers, beginning announcement for X class, referrals, random telephone sampling, etc.). If this study involves secondary analysis of data/charts/specimens only, provide information on the source of the data, whether the data is publicly available and whether the data contains direct or indirect identifiers.

Student athletes will be informed of the study demands at the initial evaluation of their ankle injury. Recruitment of individual student athletes will take place at their physical examination following the event of an acute lateral ankle sprain.

Recruitment of other UW-M students will be achieved through flyers placed in the Pavilion and Enderis Hall as well as possible referrals from Norris Health Center.

**E2. Describe the forms that will be used for each subject group (e.g., short version, combined parent/child consent form, child assent form, verbal script, information sheet):** If data from failed eligibility screenings will be used as part of your “research data”, then these individuals are considered research subjects and consent will need to be obtained. Copies of all forms should be attached for approval. If requesting to waive documentation (not collecting subject’s signature) or to waive consent all together, state so and complete the “Waiver to Obtain-Document-Alter Consent” and attach:

- Demographic form
  - Intake form compiling background information on each subject including age, gender, sport, years of sport eligibility left, scholarship status, injury severity, history of ankle injury, and experience with Xbox Kinect.
- Informed consent form
  - Consent form used at the subjects’ initial examination and screening stating the subjects’ responsibilities as well as any risks associated with the study.
- Cumberland Ankle Instability Tool
  - Baseline questionnaire identifying the presence of chronic ankle instability completed by the subjects.
- Rehabilitation Adherence Measure for Athletic Training
  - Measure completed by clinician rating the subjects’ participation, communication, and attitude during the rehabilitation process.
- Brunel Mood Scale
  - Measure asking subjects to rate their current mood state regarding various mood descriptors.
- Injury-Psychological Readiness to Return to Sport Scale
  - Measure asking subjects to rate their level of confidence to return to sport activities.
- Visual Analog Scale for pain
  - A gradient line measure in which the subject selects their level of pain where the left end of the line indicates no pain and the right end of the line indicates the most terrible pain possible.
- Foot and Ankle Ability Measure

- Measure asking subjects to rate the difficulty of daily tasks due to their ankle injury.
- Foot and Ankle Ability Measure – Sport
- Measure asking subjects to rate the difficulty of sport specific tasks due to their ankle injury.

**E3. Describe who will obtain consent and where and when consent will be obtained.** When appropriate (for higher risk and complex study activities), a process should be mentioned to assure that participants understand the information. For example, in addition to the signed consent form, describing the study procedures verbally or visually:

Information regarding the study will be provided at an initial meeting that will determine the subjects' inclusion status for enrollment into the study. Informed consent and a review of the study procedures will be provided by the Student Primary Investigator (SPI) and take place at the initial evaluation of the subject following an ankle sprain.

## SECTION F: Data Collection and Design

### Section Notes...

- F1. Reminder, all data collection instruments should be attached for IRB review.
- F1. The IRB welcomes the use of flowcharts and tables in the consent form for complex/multiple study activities.

**F1. In the table below, chronologically describe all study activities where human subjects are involved.**

- In **column A**, give the activity a short name. E.g., Obtaining Dataset, Records Review, Recruiting, Consenting, Screening, Interview, Online Survey, Lab Visit 1, 4 Week Follow-Up, Debriefing, etc.
- In **column B**, describe in greater detail the activities (surveys, audiotaped interviews, tasks, etc.) research participants will be engaged in. Address where, how long, and when each activity takes place.
- In **column C**, describe any possible risks (e.g., physical, psychological, social, economic, legal, etc.) the subject may *reasonably* encounter. Describe the **safeguards** that will be put into place to minimize possible risks (e.g., interviews are in a private location, data is anonymous, assigning pseudonyms, where data is stored, coded data, etc.) and what happens if the participant gets hurt or upset (e.g., referred to Norris Health Center, PI will stop the interview and assess, given referral, etc.).

<b>A. Activity Name:</b>	<b>B. Activity Description:</b>	<b>C. Activity Risks and Safeguards:</b>
Recruiting	<p>Following the event of an acute LAS by a student-athlete at the University of Wisconsin-Milwaukee the SPI will be contacted by the treating clinician. The SPI will describe the study and answer any questions the student-athlete may have. The prospective subject's desire to volunteer for the study will be discussed at length.</p> <p>Students with a history of LAS will respond to a recruitment flyer placed in the hallways of the Pavilion, Enderis Hall, and other campus buildings.</p>	No risk
Physical Examination	<p>In the event of an injury the treating clinician will perform a routine physical examination of the foot and ankle to appropriately assess the injury. This will include orthopedic tests to rule out fractures and assess for strength, range of motion and ligamentous stability.</p>	No risk
Screening	<p>Following a subject's expressed interest in volunteering for the study they will be asked to fill out a brief screening form regarding health history information to determine whether they are appropriate subjects for the study.</p>	No risk
Informed Consent	<p>The formal consent will be attained after the subject volunteers for the study and meets inclusion and exclusion criteria. This will be attained within 36 hours of the injury. Subjects are encouraged to ask questions if they are unsure about testing procedures. The consent process will continue informally throughout the study and participants will be reassured that they are free to withdraw from the study without penalty or harm.</p>	No risk
Acute Care Phase	<p>Routine standard of care for LAS is given to all subjects.</p> <p>Applying ice to the injured area. This is completed in order to help control the amount of swelling in the ankle.</p> <p>Compression via an elastic wrap may be applied to also help control swelling of the ankle.</p>	Minimal risk – Potential skin damage if ice is applied for longer than 20 minutes (safeguard).

	<p>Moving the ankle through pain-free range of motion (i.e. ankle circles) to regain full range of motion to help regain normal joint motion.</p> <p>The duration of this phase will be determined by the treating clinician by standard of care guidelines (approximately 12-72 hours).</p> <p>The subjects with a history of LAS, but no current injury, will be omitted from this phase of the program because they will not be suffering any acute inflammation.</p>	
Strength Training Phase	<p>Routine standard of care in strengthening of the ankle following a LAS will be provided to all subjects. Strength training with resistance bands in the motions of plantarflexion, dorsiflexion, inversion, and eversion of the ankle.</p> <p>The duration of this phase will be determined by the treating clinician by standard of care guidelines.</p>	<p>Minimal risk – Risk of muscle soreness.</p> <p>Resistance bands introduced and advanced in difficulty slowly to allow proper healing of damaged tissue.</p>
Balance Training Phase – Control Group	<p>Routine standard of care in the rehabilitation of LAS will be given to subjects assigned to the control group. Various exercises performed while balancing on injured leg, starting with simple single leg stance and progressing to single leg stance on unstable surfaces and with visual distractions.</p> <p>Other exercises that call for lateral movement, such as lateral shuffling and carioca or grapevine maneuvers, may be used during this phase. As well as plyometric exercises of line jumps from side to side and front and back.</p> <p>The duration of this phase will be a minimum of 4 weeks. These exercises will be performed 15 minutes a day for 3-5 days per week.</p>	<p>Minimal risk – Risk of ankle sprain is not increased as a result of this intervention. The balance portion is not started until after strength training has started and subject can stand on injured leg without pain.</p>
Balance Training Phase – Experimental Group	<p>Subjects will play various Xbox Kinect games while balancing on injured leg. Subjects will start with games that call for minimal movement and progress to games requiring larger and faster body movements.</p>	<p>Minimal risk – Risk of ankle sprain is not perceived to be increased as a result of this intervention. The</p>

	<p>Some of these Xbox Kinect games will require stepping from side to side and jumping over virtual obstacles.</p> <p>The duration of this phase will be a minimum of 4 weeks. These games will be played for 15 minutes a day for 3-5 days per week.</p>	<p>portion is not started until after strength training has started and subject can stand on injured leg without pain.</p>
Functional Training	<p>Routine standard of care in the rehabilitation of LAS will be provided to all subjects. Sport specific movements to mimic returning to play.</p> <p>The duration of this phase will be determined by the treating clinician by standard of care guidelines.</p>	<p>Minimal risk - Risk of ankle sprain is not increased as a result of this intervention. This portion is not started until after balance training has started and subject can run without pain.</p>
Balance Error Scoring System Test	<p>Subjects perform single leg stance or tandem stance (heel to toe stance) for 20 seconds on flat ground and foam surface with eyes closed. This test will be completed at the beginning of the balance phase and every other week through the 4 week treatment protocol.</p>	<p>Minimal risk – Risk of falling. Subjects may open their eyes to regain balance if necessary.</p>
Star Excursion Balance Test	<p>Subjects stand on involved leg and reach as far as they can in three directions with their uninvolved leg. This test will be completed at the beginning of the balance phase and every other week through the 4 week treatment protocol.</p>	<p>Minimal risk – Risk of falling. Subjects may use the reach leg for balance if necessary but will have to redo the reach trial.</p>
Survey completion	<p>Multiple surveys will be completed by the subjects at different points during the rehabilitation process.</p> <ul style="list-style-type: none"> <li>• Demographic form completed at the time of their inclusion into the study.</li> <li>• Cumberland Ankle Instability Tool will be completed at the initial session for subjects that do not have an acute LAS but a history of multiple LAS</li> <li>• Rehabilitation Adherence Measure for</li> </ul>	<p>No risk</p>



	<p>Athletic Training will be completed by the treating clinician within 36 hours of the onset of injury, at the beginning of the strength phase, the beginning of the balance phase, and upon the subjects' return to unrestricted activity in their sport.</p> <ul style="list-style-type: none"> <li>• Brunel Mood Scale will be completed every other day for the entire rehabilitation process.</li> <li>• Visual Analog Scale for pain will be completed every other day for the entire rehabilitation process.</li> <li>• Injury-Psychological Readiness to Return to Sport Scale will be completed by each subject within 36 hours of the onset of injury, at the beginning of the strength phase, the beginning of the balance phase, and upon the return to unrestricted activity in their sport.</li> <li>• Foot and Ankle Ability Measure will be completed at the beginning of the balance phase and every other week through the 4 week treatment protocol.</li> <li>• Foot and Ankle Ability Measure – Sport will be completed at the beginning of the balance phase and every other week through the 4 week treatment protocol.</li> </ul>	
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**F2. Explain how the privacy and confidentiality of the participants' data will be maintained after study closure:**

Subjects will be provided with a random 4 digit ID number that will not have any partial personal identifiers. Personal information and ID number will be stored in a locked file cabinet in a private, locked office. Study data that has been collected and personal identifiers will be not be stored together. Only those individuals with an active role in this study will have access to the data and even fewer individuals will have access to identifying information. Screening forms will be kept as record of reasons for disqualification from participation in the study. However, the name and code links will be destroyed after data collection is complete.

**F3. Explain how the data will be analyzed or studied (i.e. quantitatively or qualitatively) and how the data will be reported (i.e. aggregated, anonymously, pseudonyms for participants, etc.):**

Quantitative statistical analysis will be performed between control and experimental groups. Individual results will be pooled by group. Participants will not be identified individually.

### SECTION G: Benefits and Risk/Benefit Analysis

#### Section Notes...

- Do not include Incentives/ Compensations in this section.

**G1. Describe any benefits to the individual participants. If there are no anticipated benefits to the subject directly, state so. Describe potential benefits to society (i.e., further knowledge to the area of study) or a specific group of individuals (i.e., teachers, foster children). Describe the ratio of risks to benefits.**

Subjects in the experimental group may experience positive psychological benefits affecting their view of the injury and their enjoyment of the rehabilitation experience. The results of this study may add to emerging evidence of using active video games as a rehabilitation tool to improve patient rehabilitation adherence. It may give athletic trainers and sports medicine professionals with a low cost alternative to improve patient satisfaction. The control group has a low risk protocol and rehabilitation outcomes may be considered moderately beneficial. The experimental group has a comparable low risk protocol and rehabilitation outcomes have the potential to have greater beneficial outcomes.

**G2. Risks to research participants should be justified by the anticipated benefits to the participants or society. Provide your assessment of how the anticipated risks to participants and steps taken to minimize these risks, balance against anticipated benefits to the individual or to society.**

Risks in this intervention are considered no higher than current treatment protocols. Current clinical practices, as used in this study, contain benchmarks to help assure that the subject is ready to advance to the next difficulty and minimize risk of recurrent injury. Perceived benefits of the intervention include psychological benefits not being addressed by current rehabilitation protocols.

### SECTION H: Subject Incentives/ Compensations

#### Section Notes...

- H2 & H3. The IRB recognizes the potential for undue influence and coercion when extra credit is offered. The UWM IRB, as also recommended by OHRP and APA Code of Ethics, agrees when extra credit is offered or required, prospective subjects should be given the choice of an equitable alternative. In instances where the researcher does not know whether extra credit will be accepted and its worth, such information should be conveyed to the subject in the recruitment materials and the consent form. For example, "The awarding of extra credit and its amount is dependent upon your

instructor. Please contact your instructor before participating if you have any questions. If extra credit is awarded and you choose to not participate, the instructor will offer an equitable alternative."

- H4. If you intend to submit to the Travel Management Office for reimbursement purposes make sure you understand what each level of payment confidentiality means ([click here for additional information](#)).

**H1. Does this study involve incentives or compensation to the subjects? For example cash, class extra credit, gift cards, or items.**

Yes

No [SKIP THIS SECTION]

**H2. Explain what (a) the item is, (b) the amount or approximate value of the item, and (c) when it will be given. For extra credit, state the number of credit hours and/or points.** (e.g., \$5 after completing each survey, subject will receive [item] even if they do not complete the procedure, extra credit will be award at the end of the semester):

Subjects will receive \$50 in gift cards for volunteering (following an ankle sprain) for the study upon inclusion into the study. If subjects complete the entire study protocol they will be awarded with an additional \$50 in gift cards upon their completion.

**H3. If extra credit is offered as compensation/incentive,** an alternative activity (which can be another research study or class assignment) should be offered. The alternative activity (either class assignment or another research study) should be similar in the amount of time involved to complete and worth the same extra credit.

NA

**H4. If cash or gift cards, select the appropriate confidentiality level for payments (see section notes):**

- Level 1** indicates that confidentiality of the subjects is not a serious issue, e.g., providing a social security number or other identifying information for payment would not pose a serious risk to subjects.

- Choosing a Level 1 requires the researcher to maintain a record of the following: The payee's name, address, and social security number and the amount paid.
- When Level 1 is selected, a formal notice is not issued by the IRB and the Travel Management Office assumes Level 1.
- Level 1 payment information will be retained in the extramural account folder at UWM/Research Services and attached to the voucher in Accounts Payable. These are public documents, potentially open to public review.

**Level 2** indicates that confidentiality is an issue, but is not paramount to the study, e.g., the participant will be involved in a study researching sensitive, yet not illegal issues.

- Choosing a Level 2 requires the researcher to maintain a record of the following: A list of names, social security numbers, home addresses and amounts paid.
- When Level 2 is selected, a formal notice will be issued by the IRB.
- Level 2 payment information, including the names, are attached to the PIR and become part of the voucher in Accounts Payable. The records retained by Accounts Payable are not considered public record.

**Level 3** indicates that confidentiality of the subjects must be guaranteed. In this category, identifying information such as a social security number would put a subject at increased risk.

- Choosing a Level 3 requires the researcher to maintain a record of the following: research subject's name and corresponding coded identification. This will be the only record of payee names, and it will stay in the control of the PI.
- Payments are made to the research subjects by either personal check or cash.
- Gift cards are considered cash.
- If a cash payment is made, the PI must obtain signed receipts.
- If the total payment to an individual subject is over \$600 per calendar year, Level 3 cannot be selected.

**H5. If Level 2 or Level 3 Confidentiality is requested, please provide justification.**

NA

**SECTION I: Deception/ Incomplete Disclosure (INSERT "NA" IF NOT APPLICABLE)****Section Notes...**

- If you cannot adequately state the true purpose of the study to the subject in the informed consent, deception/ incomplete disclosure is involved.

**I1. Describe (a) what information will be withheld from the subject (b) why such deception/ incomplete disclosure is necessary, and (c) when the subjects will be debriefed about the deception/ incomplete disclosure.**

NA

**IMPORTANT – Make sure all sections are complete and attach this document to your IRBManager web submission in the Attachment Page (Y1).**

***Appendix L:***  
Study Intake Form



***Appendix M:***  
Recruitment Flyer



## Have you sprained your ankle in the past? Does it seem like you constantly roll your ankle?

A current research study on ankle sprain rehabilitation with the use of **Microsoft Xbox Kinect®** is looking for participants!

### Who can participate?

- Men or women age 18-35,
- Have had  $\geq 1$  ankle sprain in the previous 12 months or  $\geq 2$  ankle sprains over the 36 months without a history of ankle fracture,
- Do not currently have active knee, hip, or back injuries

### What will you have to do?

- Initial assessment (day 1) (30-40 minutes):
  - Brief injury history and orthopedic evaluation by a Licensed Athletic Trainer
  - Completion of baseline measures:
    - Surveys regarding your functional ability, reaction to the injury, and mood
    - 2 balance tests
- Rehabilitation sessions (up to 30 minutes, each):
  - Completed 3-5 days/week for 4 weeks
  - Perform traditional (common strength and balance exercises) rehabilitation or rehabilitation using Xbox Kinect games (balance exercises while playing games)

### Compensation:

You may receive up to \$100 in gift cards by completing this study.

### Questions?

#### Principal Investigator:

Jennifer Earl-Boehm, PhD, LAT  
414-229-3227

#### Student Principal Investigator:

Nate Maresh, LAT  
920-629-0893

*This research project has been approved by the University of Wisconsin-Milwaukee Institutional Review Board for the Protection of Human Subjects (IRB Protocol Number 14.082, approved on 10/08/2013)*