ABSTRACT

Comparison of the Effects of Aquatic and Land-Based Balance Training Programs on the Proprioception of College-Aged Recreational Athletes.

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Committee Chairperson: Dr. Lori D. Greenwood, Ph.D.

Purpose: To determine if aquatic and land-based balance training programs created significantly different improvements in levels of balance ability measured among college-aged recreational athletes. Methods: 18 active males and females, ages 18 – 35, were randomly assigned to an aquatic or land-based training group. Following baseline testing for various measures of postural control using the Limits of Stability, Unilateral Stance, and Sensory Organization Test protocols, the intervention groups performed a preset program of balance exercises three days a week for six weeks. Balance ability was then reassessed using the three test batteries to determine if any differences existed. Statistical analysis: A 2 (group) x 2 (pre-test,post-test) mixed analysis of variance was performed to determine statistical significance. Results: No significant differences were found between groups among any measures of balance ability.

Comparison of the Effects of Aquatic and Land-Based Balance Training Programs on the Proprioception of College-Aged Recreational Athletes.

by

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A Thesis

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Submitted to the Graduate Faculty of
Baylor University in Partial Fulfillment of the
Requirements for the Degree
of
Master of Science in Education

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ACKNOWLEDGMENTS

First and foremost, I would like to express deep appreciation for my committee chairperson, Dr. Lori Greenwood. You have instilled in me a desire to learn more, to ask questions, and to help others do the same. Without your guidance and direction throughout the process of writing this thesis, I would have been lost. I am genuinely thankful for your help every step along the way.

I would also like to thank those professors who also served on my thesis committee: Dr. Boucher, Dr. Barnard-Brak, Dr. Mike Greenwood, and Dr. La Bounty. Your input and assistance during the design and fulfillment of my research endeavor was immeasurable. Without the support of previous professors, Dr. Michael Brunet and Dr. Lori De Long specifically, I would have never made it to Baylor University and wouldn't have accomplished what I have. I thank you for the foundation you laid before me and the encouragement you placed upon me as I made key professional and personal decisions at Louisiana College.

I would also like to acknowledge my family for their support throughout my time at Baylor and their encouragement as I move on to greater scholarly endeavors. I am sorry for the months I've spent away from home and the things I've missed and earnestly value the sacrifices you've made for me to succeed. I am immensely blessed to be a part of our family. Lastly, I would not breathe another breath nor see the light of another day if it weren't for my Savior, Jesus Christ. I will never be worthy for the gifts He has given me and am eternally grateful for His love. He is my God, now and forever.

CHAPTER ONE

Introduction and Rationale

Background

Serious knee and ankle injuries continue to be a strong concern to athletes of many sports. The frequency of ankle and knee injuries in sport is paramount. The most common type of sprain encountered in athletics is the ankle sprain (McGuine, Grene, Best, & Leverson, 2000) while the most debilitating of injuries are seen at the knee (Gilchrist, Mandelbaum, Melancon, Ryan, Silvers, et al., 2008). An epidemiological review by Hootman, Dick, & Agel (2007) revealed that ankle sprains make up approximately 15% of all sustained injuries that occur due to athletic participation. A systematic review of 227 epidemiological studies regarding the frequency and occurrence of ankle sprains in sports was performed as well (Fong, Hong, Chan, Yung, & Chan, 2007). It was found that out of 70 sports, the ankle ranked the most injured in 24 or 34.3% of sports studied. Closely following behind was the frequency of knee injuries with 14 of 70 sports reporting them as the most common injury (Fong et al., 2007). Each injury is associated with not only pain and disability, but medical costs as well, especially in the case of surgical anterior cruciate ligament (ACL) injuries. At a cost per ACL injury of approximately $17,000, surgical and rehabilitative costs near $646,000,000 annually in the United States (Myer, Ford, & Hewett, 2004). In addition to the traumatic and psychological effects these injuries have on athletes, you must also take into account the potential loss of entire seasons of sport participation and possible scholarship funding, significantly lowered academic performance, long-term disability, and up to 105 times greater risk for radiographically diagnosed osteoarthritis in the future (Myer et al., 2004).

Having said this, it is obvious the importance that should be placed on the prevention of knee and ankle ligamentous injuries. Research is needed regarding the most efficient and effective ways to produce proprioceptive changes in the lower extremity that will lead to decreases in injury frequency and also aid in the effective rehabilitation of previous injury. Several studies have shown effectiveness of wobble board training in enhancing postural stability. Balogun, Adesinasi, & Marzouk (1992) found a significant improvement in balance ability in subjects who underwent a 6 week course of wobble board training. A study by McGuine et al. in 2000 showed that balance deficits in high school basketball players were predictors of subsequent ankle injuries. Similarly, Caraffa, Cerulli, Projetti, Aisa, & Rizzo (1996) found a significant decrease in the number of ACL injuries in a study of 600 soccer players who performed balance training exercises as part of their training regime. These results have been reproduced in more recent studies as well (Malliou, Gioftsidou, Pafis, Beneka, & Godolias, 2004; Emery, Cassidy, Klassen, Rosychuk, & Rowe, 2005). It is evident that by initiating preventative balance training programs, it is possible to reduce the risk of sustaining lower extremity injuries while also improving balance ability.

As with any rehabilitation protocol, the methods of attaining these balance improvements should be researched so the most efficient means possible can be known to those involved in athletics. On that note, it should be observed that an aquatic training environment has the potential for providing a more effective method of rehabilitating and preventing lower extremity injuries via balance training. Rationale for using aquatic balance training is seen in the various properties of water, the most important of which include buoyancy, hydrostatic pressure, and viscosity (Roth, Miller, Ricard, Ritenour, & Chapman, 2006). Buoyancy leads to a decreased weight-bearing status which can aid in decreasing the compressive forces placed on the articulating joint surfaces and decreasing the frequency of overuse and degenerative injuries (Wilcock, Cronin, & Hing, 2007). Hydrostatic pressure provides compression to the body surfaces which will aid in decreasing edema for rehabilitative cases and increasing balance by increasing joint mechanoreceptor activity (Wilcock et al., 2007). Lastly, the relatively increased viscosity of water, when compared to air, allows the application of resistance to various bodily movements in the water. When combined with a progressive balance training program, resistance created by motion can aid in increasing strength as well as increasing perturbations of joint proprioceptors which will lead to greater improvements in balance (Wilcock et al., 2007).

Purpose Statement

The purpose of this study was to determine if a significant difference exists between land-based or aquatic based balance training programs on select tests of balance among recreationally active individuals aged 18 to 35 years.

Hypotheses

H_o1: There will be no statistically significant difference in the Unilateral Stance test between the aquatic and the land based training groups.

H_o2: There will be no statistically significant difference in the Limits of Stability test between the aquatic and land based training groups.

H_o3: There will be no statistically significant difference in the Sensory Organization Test between the aquatic and the land based training groups.

General Study Overview

This study followed a 2 (group: land or water) x 2 (time: pretest, posttest) mixed design. Participants were randomly assigned to one of two groups (aquatic or land-based). Each experimental group performed a specified set of supervised balance exercises three times a week for 6 weeks. Prior to training, the participants went through baseline testing on the Neurocom Smart Equitest® using three standardized test positions to develop a measure for comparison in each group. The groups then underwent a post-training balance test at the end of the 6 week training period to determine if any improvements occurred in balance ability and whether one environment was superior to the other.

Delimitations

The study was completed following these guidelines:

1. 18 healthy and active individuals aged 18 to 35 were recruited from the student population at Baylor University and the Waco community through the use of flyers posted throughout campus and placed on the HHPR website.
2. The participants had no prior history of unresolved pain, injury or surgery to the lower extremity, head or spine nor will they have an active inner ear infection or have any other condition that may influence balance.
3. The participants were instructed to continue their regular exercise routine.

4. Baseline measures were obtained prior to initiation of balance training for each subject using the Neurocom Smart Equitest® via three testing batteries: Limits of Stability, Unilateral Stance, and Sensory Organization Test. These tests were then repeated following 18 training sessions over a 6 weeks period (3 sessions per week).
5. Participants in each group performed the same set of balance training exercises in their respective environments and progressed as outlined by the program shown in Table 1.
6. Participants performing aquatic balance training performed exercises at an approximate 50% reduction in body weight by keeping the water level at the xyphoid process.
7. All testing was performed in the Exercise and Sport Nutrition Lab at Baylor University in the Marrs-McLean Gym according to all policies and procedures within each respective laboratory.

Limitations

1. The method of participant selection was by volunteer and therefore subjects were not randomly selected. This could affect the generalizability of the outcomes to the intended population.
2. The motivation and willingness of each subject to participate varied, possibly leading to alterations in the true outcomes of the study.
3. The subjects' participation in other types of training outside of the study may have improved or weakened balance measures.
4. Group assignments were not concealed from the participants or the balance training instructor.

Assumptions

1. The participants did not perform any balance training outside of that performed as part of the study's requirements.
2. The athletes were honest regarding activity levels, athletic history, medical history, and presence of any pre-existing musculoskeletal injuries and/or balance disorders that could have affected outcome measures.
3. Measures obtained by the Neurocom Smart Equitest® and specific testing positions used provided reliable and valid means of assessing postural control and the equipment to obtain these measures was calibrated appropriately.
4. The subjects were healthy and physically active, participating in at least 20-30 minutes of moderate activity three times a week and continued to perform at this level for the duration of the study.

Definition of Terms

1. Proprioception: the ability to sense the position of a joint or body part in motion
2. Balance: the ability to maintain a position and react to a perpetuating force (Roth et al, 2006).
3. Postural Control: the ability to maintain an upright posture and to keep the center of gravity within the limits of the base of support (Lee & Lin, 2008).
4. Musculoskeletal injury: refers to damage of muscular or skeletal structures, usually due to strenuous activity, that inhibits an individual's ability to perform functional tasks (Shier, Butler, & Lewis, 2004).

5. Balance disorders: a disturbance of the vestibular, visual, or sensorimotor systems that causes an individual to feel unsteady, giddy, woozy, or have a sensation of vertigo (Shier et al, 2004).
6. Active population: individuals who engage in moderate exercise for 20 to 30 minutes for a minimum of three times per week (Butte, Treuth, Mehta, Wong, Hopkinson, & O'Brian-Smith et al., 2003).

CHAPTER TWO

Literature Review

Physiology of Balance

Balance, or postural stability, is the ability to maintain a position and react to a perpetuating force (Roth et al). Many physiological components of the human body allow us to perform such reactions. Of most importance regarding maintaining balance is proprioception: the ability to sense the position of a joint or body part in motion (Brown, Miller, & Eason, 2006). Several types of sensory receptors located throughout the skin, muscles, joint capsules, and ligaments give the body its ability to recognize both internal and external environmental changes within each joint and ultimately lead to improvements in balance. This concept is important in a clinical orthopedic setting due to the fact that enhancing balance abilities in athletes helps them to achieve superior athletic performance as effective motor control is defined by accurate sensory information concerning both the external and internal environmental conditions of the body (Riemann & Lephart, 2002). Proprioception is produced through the simultaneous actions of the vestibular, visual, and sensorimotor systems, each of which plays a significant role in maintaining postural stability. Of most concern in enhancing proprioception are the functions of the sensorimotor system. Encompassing the sensory, motor, and central integration and processing components involved in maintaining joint homeostasis during bodily movements, the sensorimotor system includes the information received through nerve receptors located in ligaments, joint capsules, cartilage, friction, and the bony geometry involved in each joint's structure. Mechanoreceptors are specialized sensory receptors responsible for quantitatively transducing the mechanical events occurring in their host tissues into neural signals (Riemann & Lephart, 2002). Those that are responsible for proprioception are generally located in joint muscles, tendons, ligaments, and capsules while pressure sensitive receptors are located in the fascia and skin (Riemann & Lephart 2002).

Four major types of mechanoreceptors that aid in proprioception exist, including Ruffini receptors, Pacinian receptors, Golgi-tendon-organs (GTO), and muscle spindle. Ruffini and Pacinian receptors are associated with sensations of touch and pressure and are generally located in the skin (Shier et al., 2004). Ruffini receptors are considered to behave as both static and dynamic receptors based on their low-threshold, slow-adapting characteristics. Through pressure changes they signal static and dynamic tensile changes in the skin and are very sensitive to stretching (Rieman & Lephart, 2002a). Pacinian receptors, on the other hand, are rather fast-adapting, yet low-threshold receptors that are considered to be more dynamic receptors (Rieman & Lephart, 2002a). While also pressure sensors, Pacinian receptors detect heavier pressures and recognize acceleration and deceleration of movement (Shier et al., 2004). Playing a larger role in sensing joint position during movement are Golgi Tendon Organs and muscle spindle. First off, GTOs are located at the musculotendinous junction and are responsible for monitoring the force of muscle contraction to prevent muscles from being overloaded (Brown et al., 2006). Connected to a set of muscle fibers and innervated by a sensory neuron, GTOs have high thresholds and are stimulated by increased muscle tension. When increased muscle tension is recognized, GTOs produce a reflex that inhibits contraction of the muscles they occupy, inadvertently protecting the muscle attachments from being pulled away from their insertions by excessive tension (Shier et al., 2004). Muscle spindles, on the other hand, consist of specialized afferent nerve endings that are wrapped around modified muscle fibers, called intrafusal fibers, that are sensitive to muscle lengthening (Brown et al., 2006). When these fibers are stimulated by increased length changes, rather than causing a relaxation seen with the GTO, they stimulate a contraction of the muscles in which they reside (Shier et al., 2004).

The importance of these mechanoreceptors in proprioceptive ability becomes evident in the event of musculoskeletal injuries and how interruptions in the stimulation of them affect the motor control essential to attaining superior athletic performance. There are two basic roles performed through the use of proprioceptive information regarding motor control (Rieman & Lephart, 2002b). The first of these involves the role of proprioception with respect to the external environment. Oftentimes the operations of the musculoskeletal system have to be adjusted to accommodate unexpected perturbations in the external environment (Rieman & Lephart, 2002b). For example, when an athlete is running downfield expecting a stable running surface during competition yet he takes a step on wet, soggy ground that doesn't provide much grip for cutting motions, proprioception kicks in so that the athlete can adjust to the unexpected terrain appropriately. Additionally, the planning of movement requires attention to environmental factors (Riemann & Lephart, 2002b). An example of this function can be explained from an athletic perspective when a soccer player jumps up to head a ball while being pressured by an opposing player. Perturbations applied by that opposing player cause the athlete to recognize alterations in his or her position and, as a result, consequential modifications in landing method occur. The second role of proprioception in motor control that is essential to superior athletic performance involves the planning and modification of internally generated motor commands (Riemann & Lephart, 2002b). This function, from an athletic perspective, is primarily seen in the generation of forcefully appropriate muscular contractions during performance. As an athlete moves a limb to perform functional tasks associated with his sport, each angular change in joint position changes the mechanical advantages associated with all the muscles that cross each joint used for that motion (Riemann & Lephart, 2002b). Proprioception helps the motor control system account for multiple motions that occur simultaneously by allowing the appropriate amount of muscle activation and controlling the movements that each joint induces on the others used with each functional task. When an athlete experiences tendinous, ligamentous, or capsular injury, or merely has proprioceptive deficits naturally, the mechanisms by which proprioception occurs are inhibited and each of the previously discussed roles are diminished. This can greatly affect athletic performance and has shown to increase risk of injury. These risks will be discussed subsequently.

Balance Training and Injury Rates

Much research has been performed regarding the use of balance training for injury prevention purposes, particularly relative to ankle sprains and chronic ankle instability. Only one study exists concerning aquatic balance training and it does not address injury reduction rates (Roth et al., 2006). Due to the lack of research directly related to this study, a review of related literature concerning the relatively reduced rates of injury as a result of balance training on land will be discussed.

Many studies on balance training have shown to improve measures of postural control while also reducing the risk of injury or re-injury. In a study by Kidgell, Horvath, Jackson, & Seymour (2007), 6 weeks of dura disc balance training was compared to 6 weeks of the same training protocol on a mini-trampoline. The researchers used postural sway measures of medial-lateral and anterior-posterior sway during a single leg stance to assess for improvements in balance after having completed the training protocols. While no significant differences were found between modes of training, significant improvements in postural sway measures were observed between the intervention groups and the control group who merely performed testing. Another study, by Emery et al. (2005), studied the effectiveness of a home-based balance training protocol using a wobble board in improving static and dynamic balance as well reducing sports related injuries among healthy adolescents. This study randomly selected 2 physical education students from 10 of 15 high schools in a school district to participate in the study. They were randomly assigned to either an intervention group or a control group. The intervention group participated in a daily 6-week and then a weekly 6-month home-based balance training program. After 6 weeks, postural sway assessment via timed single leg stance on firm ground and on foam revealed improvements in the intervention groups but not in the control group. Additionally, self-reported injury data was collected over the 6 month follow-up period and a protective effect of balance training was evident. Twelve subjects reported athletic injuries over the 6-month observation period, two in the intervention group and 10 in the control group.

A study by Lee & Lin looked for improvements in postural stability and ankle proprioception among subjects with unilateral functional ankle instability (2008). The researchers used a 12 week training program with a biomechanical ankle platform system (BAPS board) and a progression protocol to reach for improvements in proprioception. Balance testing using single leg stance with eyes open and eyes closed was implemented for measures of postural stability. The researchers found significant improvements in the mean radius of center of pressure on unilateral standing in the functionally unstable ankles after 12 weeks of balance training.

Rasool and George (2007) analyzed the effect of single-leg dynamic balance training on dynamic stability in healthy male athletes. Assessed using the Star Excursion Balance Test, participants performed balance tests at baseline, 2 weeks after initiation of balance training, and again at 4 weeks at the close of training. The exercise group's trained, or dominant, limbs showed significant improvements in balance test parameters in all individual directions at 2 weeks and continued to improve significantly at 4 weeks when compared to the control group. The untrained, or non-dominant, limbs showed significant improvement in four of the eight outcome measures as compared to the control group. These results point out the efficacy of even short duration balance training and the implications it may have in the prevention of injury if used during preseason training are paramount.

MeKeon and Hertel (2008) performed a systematic review of postural control and lateral ankle instability to determine if prophylactic balance training could reduce the risk of sustaining a lateral ankle sprain, if balance training could improve treatment outcomes associated with acute ankle sprains, and whether balance training could improve treatment outcomes associated with chronic ankle instability. The review revealed a 20% to 60% relative reduced risk for sustaining a lateral ankle sprain as a result of balance training. Particularly those athletes with a history of ankle sprains had a consistent and significant reduction in the risk of sustaining recurrent ankle sprains. With regard to the treatment outcomes of acute ankle sprains, the review revealed 3 articles that found a 54% to 74% relative reduced risk of sustaining recurrent ankle sprains after undergoing balance training following an acute ankle sprain. Finally, there were no significant findings regarding the effect of balance training on improving treatment outcomes of individuals who suffer from chronic ankle instability.

Another study looked at the effect that balance training had on the risk of ankle sprains in high school athletes (McGuine & Keene, 2006). In this study 765 high school soccer and basketball players were assigned to either an intervention group that participated in a balance training program or a control group that performed only standard conditioning exercises. Athletic exposures and ankle sprains, as diagnosed by a Certified Athletic Trainer, were recorded and differences in frequency of sprains per exposures were calculated (McGuine & Keene, 2006). Similarly to previously reported results, the study showed that the rate of ankle sprains was significantly lower for subjects in the intervention group. Athletes with a history of an ankle sprain had a 2-fold increased risk of sustaining a sprain while athletes who performed the intervention program decreased their risk of a sprain by one half (McGuine and Keene, 2006). These results were duplicated in a study by Malliou et al. (2004). They studied the effects that balance training had on the occurrence of lower extremity injuries and found that the experimental group, who performed balance training, had 60 lower limb injuries while the control group had 88 injuries. Regarding specific injury types, ankle sprains occurred nearly 1.5 times more in the control group than in the intervention group (22 vs. 38).

A study by Mohammadi (2007) compared three different preventative methods on reducing the recurrence of ankle inversion sprains in male soccer players. These preventative methods included balance training, strength training, and orthoses. They found that the incidence of ankle sprains was significantly lower in the balance training group when compared to the control group while the findings respective to the strength and Orthoses groups were insignificant.

Balance Training and Anterior Cruciate Ligament Injuries

While many studies have been performed regarding the decrease in ankle injuries as a result of balance training, it should also be noted that similar theories exist regarding the prevention of knee injuries, more specifically anterior cruciate ligament (ACL) injuries. Many studies have been performed to assess the effect of balance training and other preventative techniques on the reduction of ACL injury rates and treatment outcomes of ACL injuries. Theories supporting balance training in the prevention of ACL injury suggest that proprioceptive training promotes neuromuscular mechanisms responsible for the co-contraction of agonist and antagonist muscles that enhance active joint stability, a component essential for superior athletic performance (Hrysomallis, 2007). However, balance training has also been shown to have a negative effect on ACL injury rates, especially in females (Hrysomallis, 2007). Therefore, a multi-faceted training protocol is often recommended for ACL injury prevention (Hrysomallis, 2007).

In a meta-analysis of balance training and associated injury risks, six studies were examined and it was found that balance training reduced the incidence of ACL ruptures by 7-fold in male soccer players; however, it was also associated with a significant increase in the risk of major knee injuries in female soccer players as well as overuse injuries in male and female volleyball players (Hyrosomallis, 2007). The study that found these results was the only study that used a wobble board in its training protocol and, therefore, the researcher suggests that differing methods of proprioceptive training might influence the rate of ACL injuries in a more positive manner (Hrysomallis, 2007). The researcher also suggested that multi-faceted interventions that incorporated proper jumping and landing techniques as well as rapid-change-of direction exercises could be a more effective means of reducing ACL injuries (Hrysomallis, 2007).

A previously mentioned study by Malliou et al. (2004) found a decrease in knee injuries as a result of proprioceptive training in a sample of young soccer players. Injuries were recorded over one competition period and results showed that twice as many knee ligament injuries occurred in the control group than did in the intervention group (28 vs. 14). Another study by Caraffa et al. in 1996, as reported in a report by Myer et al (2004), evaluated the effect of balance board exercises on noncontact ACL injury rates in elite male soccer players. It showed that athletes who participated in proprioceptive training before their competitive season had a significantly reduced rate of knee injuries. Although no other results were found by the authors that duplicated these results, Myer et al. (2004) were able to find a study that elaborated on the balance training protocol suggested by Caraffa et al. by adding a focus to improve awareness and knee control during standing, cutting, jumping, and landing. They were able to reduce the incidence of ACL injury in women's elite handball players over 2 competitive seasons (Myer et al., 2004).

A study by Soderman, Werner, Pietila, Engstrom, & Alfredson, (2000) as reported in a meta-analysis by Padua & Marshall (2006) investigated overall injury patterns among female soccer players. The players were given their own balance boards and were provided with a printed handout of a balance training program consisting of 5 exercises that would take approximately 10 -15 minutes at home. Contrary to the previously mentioned findings of Caraffa et al., there was no difference between control and intervention groups in the incidence of traumatic injuries. The researchers suggest possible reasons for this difference including gender, playing division, or total amount of balance training (Padua & Marshall, 2006). Of particular interest regarding this study, however, is that four of the five ACL injuries experienced during the study period were to subjects within the balance training group. This idea of a negative effect specific to balance training exercises on a wobble board seen with a previously mentioned study surfaces again; further research is recommended to determine if specific balance training exercises and equipment produce differing results regarding ACL injury prevention (Padua & Marshall, 2006).

Another study reported by Padua & Marshall (2006) investigated the effect of a phased balance training intervention on different handball divisions. The study used an initial season as a control season and the two consecutive seasons following as intervention seasons. Injury data was collected from 60 teams through an injury-surveillance system. During the 5 to 7 week pre-intervention season period, the athletes were instructed to perform balance training exercises three times a week and to decrease training to once a week once the competitive season began. Twenty-nine ACL injuries were reported during the control season while 23 and 17 ACL injuries were reported during the first and second intervention seasons, respectively. There was no significant difference, however, between the incidence of ACL injuries in the control group compared to the intervention group. Of interest is the trend seen between level of skill and ACL injury frequency when the groups were separated by skill. The elite division showed a positive training effect while the second and third divisions showed no significant effects of training on ACL prevention.

A final study regarding the effects of balance training on ACL injury prevention performed by Petersen, Braun, Bock, Schmidt, & Weimann et al. (2005) showed a decrease in the intervention compared to the control group. The study looked at 134 players following an injury prevention program that included 3 main components: balance board exercises, jump exercises, and balance mat exercises. There were 5 ACL injuries in the control group compared to a single ACL injury in the intervention group. Though this did not reach statistical significance, the ACL injury risk was 80% lower in the intervention group. A meta-analysis by Hewett, Ford, & Myer (2006) went on to make recommendations regarding ACL prevention programs based on analysis of success rates of differing methods of intervention. The researchers suggested 3 common elements of prevention programs: a Plyometric component, a biomechanical analysis and correction component, and a balance and core stability training component (Hewett et al., 2006).

Balance training has not only been shown useful in the prevention of anterior cruciate ligament injury, but also in its rehabilitation. In a study by Vathrakokilis, Malliou, Gioftsidou, Beneka, & Godolias (2008), twenty-four patients who had undergone similar ACL reconstruction surgeries were randomly assigned into either a balance training group or a control group. Using the Biodex Stability System to assess patients' balance in single limb stance, the authors noted significant pre-training differences in proprioceptive ability between healthy and reconstructed legs. After the 8 week balance training program, all balance performance indicators significantly improved in the balance training group while no difference was found among those in the control group. This goes to show that even a long period after rehabilitation of the ACL reconstruction, patients still had significant proprioceptive deficit in comparison to their healthy legs. However, with the 8-week balance training program utilized in this study, that deficit was decreased, thus supporting the role of balance training in the treatment of knee injuries in addition to those of the ankle.

Aquatic Therapy

Many physiological responses of the human body to immersion in water have lead to its many therapeutic uses in the clinical rehabilitative and sport conditioning environments. The contributing factors of hydrostatic pressure and buoyancy allow exercise in an aquatic environment to have several advantages over a gravity-influenced environment (Roth et al., 2006). This idea provides tremendous aid in rehabilitation settings when full weight bearing is contraindicated.

First of all, water immersion provides various functions as a therapeutic modality in addition to its gravity-eliminating qualities. In the event of most musculoskeletal injuries, the inflammatory response sets in immediately and leads to decreased ranges of motion and, in some cases, pain. Water immersion helps reduce injury-associated inflammation by two methods: cryotherapy and compression (Wilcock et al., 2005). Cryotherapy involves the use of cold modalities, in many cases ice, to reduce pain, muscle spasm, and associated inflammation. In relation to this study, the physiological phenomenon that will be most applicable is the compressive effect water immersion has on our extremities. Water exerts a compressive force on the body called hydrostatic pressure (Wilcock et al., 2006). This pressure varies relative to depth. The proportional change in pressure with depth causes an upward squeezing action on the body, which at one meter depth is almost equal to normal diastolic blood pressure (Wilcock et al., 2006). Due to this phenomenon, interstitial fluids are displaced from the extremities into the lymphatic drainage system and back toward the central cavity (Wilcock et al. 2006). This displacement of fluid may increase the translocation of substrates from the muscles, increase cardiac output, and reduce peripheral resistance as well as reduce edema (Wilcock et al., 2006). Additionally, internal tissue hydrostatic pressure and capillary filtration pressure may improve the reabsorption of interstitial fluids (Wilcock et al., 2006).

The second applicable property of water in the case of hydrotherapy is the feeling of weightlessness that is caused by the principle of buoyancy. Water exerts a net upward force, or thrust, on a body immersed in it, and this principle helps to support all or part of the weight of the body (Wilcock et al., 2006). This effect leads to a reduction in the gravitation forces that act on the musculoskeletal system, allowing for a greater relaxation of muscles that are constantly working against gravity and reduces the force that is placed on the articulating structures. Immersion may also improve balance abilities by increasing proprioceptive input to the immersed body and provide it with greater body alignment and stability (Roth et al., 2006). Sensory feedback may also increase, thus promoting a sense of body awareness because resistance to movement through a viscous fluid like water is greater than resistance through air (Roth et al., 2006). This is evidenced by a study performed by Resende, Rassi, & Viana (2008)regarding the effects of aquatic balance training on the balancing abilities of elderly women. The researchers used a 12 week low to moderate intensity hydrotherapy program for balance which consisted of a familiarization phase, a stretching phase, and a phase of static and dynamic balance exercises. Balance testing at six weeks and twelve weeks showed a significant increase in the elderly women's balance as well as a reduction in the scores in a scale of risk of falls. While the elderly aren't the target population for this study, it should be highly indicative of what a higher intensity balance program can do for the balance of well-adapting collegiate recreational athletes.

The resistive property of water also aids rehabilitative efforts by providing a method of strengthening while decreasing the amount of pressure placed on articulating joint surfaces. Many rehabilitation implements are available to aid in enhancing each of the previously listed properties of hydrotherapy. Various forms of ankle cuffs, fins, dumbbells, and other rehabilitative equipment use the principles of buoyancy and water resistance to enhance strength, endurance, and, in the case of this study, balance.

While literature regarding the use of aquatic therapies in injury prevention and rehabilitation is limited, it does exist. For example, Roth et al. selected 24 healthy subjects and randomly assigned them to one of three groups: aquatic, land, or control. They performed pretest measures of static and dynamic balance by measuring center of pressure variables via a Kistler 9421-A11 force plate. Outcome measures included radial area, y-range (anteroposterior sway), and x-range (mediolateral sway) taken during single leg, tandem, single leg foam, and tandem foam stance. They then implemented four weeks of balance training for the aquatic and land groups. Testing was repeated at 2 weeks, 4 weeks, and 6 weeks (2 weeks follow-up). The authors found a significantly smaller x-range in the aquatic group than the land and control groups as well as a significantly smaller radial area. However, these findings did not lead to recommendations by the authors regarding the implementation of aquatic balance training programs. They concluded in the commentary section of their reported findings that aquatic and land-based balance training are equally effective in producing balance enhancements. The confusing nature of these comments suggest a need for further research regarding the differences between balance training on land and in the water.

In a study examining the postural sway characteristics possessed by women with lower extremity arthritis before and after an aquatic exercise intervention, measures of postural sway were significantly improved after 6 weeks of training (Suomi & Koceja, 2000). Subjects in the aquatic exercise group showed significantly improved lateral COP sway with a 26% improvement and total COP sway with an 18.1% improvement in an eyes open single-leg stance. No significant changes were seen in the control group. In an eyes closed single-leg stance, the aquatic exercise group improved total sway by 28.5%, lateral sway by 30.5%, and sagittal sway by 11.5%, while the control group showed no significant changes in any outcome measures. These results show that in addition to improving balance ability in injured athletes, aquatic balance training can also be a useful tool in the improvement of balance deficits experienced by arthritic patients.

It has also been suggested that aquatic therapy can lead to improvements in many areas of deficit associated with an ACL reconstruction. In 2008, a study by Zamarioli, Pezolato, Mieli, & Shiman compared the effects of water rehabilitation to those experienced by another group on land. While findings were not significant, the aquatic group did show greater weekly reductions in pain, greater increases in knee flexion range of motion, slightly greater muscle strength during knee flexion and extension, and greater decreases in swelling per week. These results show that rehabilitative goals may be met more quickly when an aquatic environment is used during recovery.

Aquatic therapy is not only effective for bone and ligamentous conditions but also for those with musculoskeletal syndromes, such as fibromyalgia. In 2008, a randomized controlled trial was performed to determine the effects of aquatic therapy on global symptomology—pain, tender point count, sleep disturbances, physical function and cognitive function—on patients with fibromyalgia syndrome (Munguia-Izquierdo & Legaz-Arrese, 2008). Subjects participated in a 16-week aquatic training program that included strength training, aerobic training, and relaxation exercises. At the conclusion of the 16-week period, the exercise group showed significant improvement in tender point count, sleep quality, cognitive function, and physical function while the control group showed no improvement. This result goes to show that aquatic therapy can be an effective modality in the treatment of many forms of musculoskeletal injury.

Computerized Dynamic Posturography

In a clinical setting, various methods of balance assessment are used. In the case of athletics-related injury, observations are typically made regarding gait, posture, ability to complete position-specific tasks, and others. Changes in balance are measured via clinical tests such as the Balance Error Scoring System (BESS Test) or the Rhomberg test, where the number of errors an individual makes while performing single, double, or tandem-stance under a variety of conditions are summed to objectively quantify the individual's balance ability (Monsell, Furman, Herdman, Konrad, & Shepard, 1997). While this procedure works for gross measurements of balance, more precise methods are warranted for recognizing more detailed characteristics of balance, particularly in determining improvements in balance ability following an intervention for conditions such as musculoskeletal injury, stroke, concussion, or diagnosis of vestibular disorders (Visser, Carpenter, Kooij, & Bloem, 2008). For this reason, methods of assessment that utilize various types of equipment have been developed recently that allow detailed analysis of balance during static and dynamic conditions and also allow separation of the various systems that govern an individual's balance ability (i.e. the visual, vestibular, and somatosensory systems). In this study the Neurocom Smart Equitest® (Neurocom International, Inc.; Clackamas, OR) will be used.

The Neurocom Smart Equitest® device consists of a movable force plate and a visual surround that can move in a sway-referenced manner, along with a harness that practically eliminates risk of fall during testing (Neurocom International, Inc., 2000). Several different testing protocols have been developed using the Neurocom Equitest® system. For purposes of this study, three specific tests will be utilized: the Sensory Organization Test, Limits of Stability, and Unilateral Stance. The Sensory Organization Test (SOT) provides information about the integration of visual, proprioceptive and vestibular components of balance through the performance of six conditions: (1) stable platform with eyes open and a stationary visual surround, (2) platform stable with eyes closed, (3) platform stable with eyes open and a moving visual surround, (4) platform moving with eyes open and a stationary visual surround, (5) platform moving with eyes closed, and (6) platform moving with eyes open and a moving visual surround (Neurocom International, Inc., 2000). For the four conditions during which the visual surround or the platform is moving, the movement of each respective component of the device is coupled to the sway of the patient's attempt to stabilize the platform or visual surround rotation. This design is intended to isolate which sensory system is used during those specific conditions in which reduced or distorted sensory information from the visual and somatosensory systems is provided (Furman, 1994).

The second test that will be utilized via the Neurocom Smart Equitest® is the Limits of Stability (LOS). For each of eight trials, the participant is asked to maintain their center of gravity over their base of support. To aid the participant in maintaining this position, a computer screen displays a cursor representing the participant's center of gravity position relative to a center target. On command, the participant moves the center of gravity cursor as quickly and accurately as possible towards one of eight targets located on the Limits of Stability perimeter. The subject must hold the position as close to the target as possible for ten seconds (Neurocom International, Inc., 2000). The goal of this test is to quantify each subject's ability to voluntarily sway towards various locations in space and briefly maintain stability at those positions (Geldhof, Cardon, Bourdeaudhuij, Danneels, Coorevits, et al., 2006). The third and final test that will be utilized for detecting improvements in balance during this study is the Unilateral Stance (US). During this test, the subject will stand on each leg for three 10 second trials while under two different conditions: eyes open and eyes closed (Neurocom International, Inc., 2000).

Just as other methods of computerized dynamic posturography have shown acceptable levels of reliability and validity, the SOT, LOS, and US tests are no different. A study by Ford-Smith, Wyman, Elswick, Fernandez, & Newton (1995) looked at the 1-week test-retest reliability of the SOT in non-institutionalized older adults. The authors calculated intra-class correlation coefficients for the first trial of each condition of the SOT and also for each condition over three trials. The ICC for the SOT first trial data ranged from 0.15 in condition 3 to 0.70 in condition 5. The ICCs for SOT average of three trials ranged from 0.26 in condition 3 to 0.68 and 0.64 in conditions 5 and 6. The SOT composite score exhibited good reliability with an ICC of 0.66 with a 90% confidence interval of 0.49 to 0.79. These results have been replicated in other studies. Henderson (1995) performed a pilot study to determine test-retest reliability of the SOT among three different age groups. The ICCs for conditions 1 and 2 ranged from .36 to .55 and the ICCs for conditions 3 through 6 ranged from .73 to .99; these results and results by Ford-Smith et al. show the tendency for greater reliability among the more difficult tasks required of the SOT (i.e. conditions 3-6).

Limits of Stability has received somewhat higher reliability scores than those of the SOT. A study specifically looking at the reliability of LOS measures among healthy subjects ranging from 20 to 32 years of age found excellent ICC values with regards to maximum center of gravity excursion ranging from 0.88 to 0.93 (Brouwer, Culham, Liston, & Grant, 1998). Similarly, in a study among stroke patients, authors Liston & Brouwer (1996) found that the LOS test was the only reliable measure when compared with two other dynamic balance tests that required subjects to shift their weight in anterior-posterior and medial-lateral manners. The authors found ICC values of 0.88 for movement time and 0.84 for movement path. They also validated the three tests against the Berg Balance Scale and 10m gait velocity, two commonly utilized clinical assessment tools for balance ability. It was shown that 5 out of 6 dynamic variables reflecting dynamic balance abilities were significantly associated both clinical tools. Lastly, Geldhof et al. (2006), in a study to determine test-retest reliability among static and dynamic balance in 9 and 10 year olds, found ICCs between 0.44 and 0.62 for all composite LOS parameters while separate LOS parameters showed fair to good and excellent reliability for nine parameters with ICCs between 0.46 and 0.81. Unilateral Stance (US) has also shown to be a reliable measure of balance ability. Bouche, Veerle, Cambier, Caemaert, & Danneels (2004) compared postural control in unilateral stance between healthy controls and lumbar discectomy patients with and without pain. The authors performed all balance tests three times to test for reliability and found ICC values ranging from 0.70 to 0.98.

CHAPTER THREE

Methodology

Participants

In this study, 18 healthy and moderately active males and females between the ages of 18-35 were recruited on a voluntary basis via fliers posted around the Baylor University Campus and on the HHPR website. According to the qualifications as stated by American College of Sports Medicine (ACSM), subjects were less than 40 years of age and had no symptoms of or known presence of heart disease or major coronary risk factors. Additionally, participants met the criteria for being moderately active individuals, which included engaging in moderate exercise for 20 to 30 minutes $\geq$ 3 times per week (Butte et al., 2003). It was also required that each participant engage in weight bearing activity that did not include resistance training only. Subjects had no contraindications to exercise as outlined by the American College of Sports Medicine (ACSM) and did not consume any ergogenic nutritional supplements (excluding multi-vitamins) 3 months prior to the study. Participants that a) had a prior history of unresolved pain, injury or surgery to the lower extremity, head or spine or b) had an active inner ear infection, c) were unable to perform the land or water-based exercise protocol or the balance tests on the Neurocom Smart Equitest®, d) had a fear of water (hydrophobia), or e) had any allergies to pool related chemicals such as chlorine or bromine were excluded from participation in this study.

Study Site

Familiarization and testing using the NeuroCom Smart Equitest® was performed in the Exercise Biochemical Nutrition Laboratory which is located in the Rena Marrs McLean Gymnasium on Baylor University's campus in Waco, Texas. All water-based balance training was performed in Baylor University's McLane Student Life Center pool. All land-based balance training was performed in room 122 of the Rena Marrs McLean Gymnasium.

Independent and Dependent Variables

Independent Variables:

The independent variables for this study were the training environments in which exercises were performed (land or water).

Dependent variables:

The dependent variables for this study were: Limits of Stability Test, Unilateral Stance Test, and the Sensory Organization Test.

Experimental Procedures

Participants expressing interest in participating in this study were interviewed on the phone and/or asked preliminary inclusion questions via email to determine whether or not they could be included in the study. Participants believed to meet eligibility criteria were then invited to attend an entry/familiarization session. Once reporting to the ESNL lab, participants completed medical history and supplement/activity questionnaires, and underwent a general physical. Participants meeting entry criteria were then familiarized to the study protocol via a verbal and written explanation outlining the study design. They also practiced a shortened version of each balance test to be performed for pretesting and the balance training exercises they would later perform. At the end of the familiarization session, subjects were then given an appointment time to perform baseline assessments.

During baseline testing, subjects' height and weight were measured so that appropriate balance measurements could be calculated. Subjects performed a 5-minute warm-up on a cycle ergometer at 60 rpm and 60 w followed by 3 supervised stretches of 20 second duration for the quadriceps/hamstrings/gastroc-soleus complex bilaterally as demonstrated by the tester. After the warm-up, each subject went through balance testing on the Neurocom Smart Equitest® in the following order:

Limits of Stability (LOS): The LOS test was conducted on a stationary dual forceplate. The LOS quantifies the maximum distance a person can intentionally displace their center of gravity (COG), i.e., lean their body in a given direction without losing balance, stepping, or reaching for assistance. For each of 8 trials, the subjects maintained their COG centered over the base of support as indicated by a cursor on the computer screen. On command, the subjects moved the COG cursor as quickly and accurately as possible to a second target located on the LOS perimeter. They then held this position. The subject was allowed up to 8 seconds to complete each trial for a maximum test time of 64 seconds.

Unilateral Stance (US). This test was conducted on a stationary dual force plate. The US quantifies postural sway velocity with the patient standing on either the right or left foot on the force plate, with eyes open and with eyes closed. The length of each trial was 10 seconds. The US test evaluated each foot individually, with 3 trials per eyes open and eyes closed conditions, for a total of 12 trials.

Sensory Organization Test (SOT): The SOT consisted of a sequence of 6 conditions of 3 trials lasting 20 seconds each.

Condition 1: Subjects stood on a fixed forceplate with their eyes open.

Condition 2: Subject stood on a fixed forceplate with their eyes closed.

Condition 3: Subjects stood on a fixed forceplate with eyes open while the visual surround moved in a 1:1 ratio to the subjects' degree and direction of sway in order to disturb their visual field.

Condition 4: Subjects stood with their eyes open while the forceplate tilted anteriorly and posterior in a 1:1 ratio to the subject's degree and direction of sway.

Condition 5: Subjects stood with their eyes closed while the forceplate tilted anteriorly and posteriorly in a 1:1 ratio to the subject's degree and direction of sway.

Condition 6: Subjects stood with their eyes open while the forceplate tilted anteriorly and posteriorly in a 1:1 ratio to the subject's degree and direction of sway and the visual surround moved in a 1:1 ratio to the subjects' degree and direction of sway.

Instrumentation

During the 6-week balance training protocol, certain rehabilitative devices were utilized to enhance the difficulty of the exercises theorized to further the improvements made the in balance abilities of the subjects. A wobble board (BodyTrends; West Palm Beach, Florida) for each participant was used for many of the training exercises. This piece of equipment is composed of a 16-inch circular platform that has a 2-inch half-sphere attached to the bottom, allowing 15-20 degrees of motion in all directions.

Measurements of postural balance were collected utilizing the Neurocom SmartEquitest® (Portland, OR). The SmartEquitest® consists of a dual force plate which remains stable, and a dynamic force plate which tilts in a plane horizontal to the floor or translates in the anterior/posterior direction. The patient's field of view is blocked by a visual surround that can also tilt. In addition, the dynamic force plate has a patient harness system suspended from it for use during dynamic force plate testing.

Training Protocol

After baseline testing, subjects were allocated to a land training group or an aquatic training group. A group training schedule was then created that allowed each participant in the intervention groups to perform 3 exercise sessions per week for 6 weeks. Therefore, participants who met the inclusion criteria were required to complete a total of 18 exercise sessions. For each session, subjects warmed up by performing a controlled series of jogging in place and jumping jacks for a 5-min duration followed by the same standardized series of stretching exercises as performed during baseline testing. After the warm-up, each group then started the balance training program in their respective environments. The aquatic training group performed exercises in a graded pool that allowed participants of varying heights to perform balance training exercises with the water level reaching the xyphoid process. This location allowed for a 50% reduction in body weight (Harrison, Hillman, & Bulstrode, 1992). Each training session lasted approximately 30-45 minutes.

Due to the lack of information concerning aquatic rehabilitation, the balance training program that was utilized for this study (Table 1) was created using a combination of several methods that were used in studies involving land-based balance training (Roth et al., 2006; Rozzi, Lepahart, Sterner, & Kuligowski, 1999; McGuine and Keene, 2006). Exercises and equipment were chosen specifically for use in both land and aquatic environments, as identical training programs were used for each. Subjects in the water group performed exercises barefoot while those in the land group performed them while wearing athletic shoes, due to discomfort that the abrasive surfaces of the boards caused during full weight-bearing. The progression of the training protocol is shown below. If a subject contacted the ground three or more times during an exercise, he/she remained a level lower for that exercise until it could be completed successfully.

Table 1

Balance Training Program

Exercise:	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
	Firm surface	Firm surface	Wobble Board	Wobble Board	Wobble Board	Wobble Board
SL Stance	3x30s; EO	3x30s; EC	3x30s; EO	3x30s; EO	3x30s; EC	3x30s; EC
SL Stance w/ leg swing	3x30s; EO	3x30s; EC	3x30s; EO	3x30s; EO	3x30s; EO	3x30s; EC
SL squat	3x10; EO	3x10; EO	3x10; EO	3x15; EO	3x20; EO	3x25; EO
Balance & reach	3x10	3x10	3x10	3x20	3x20	3x20
A-P Tilt	----	----	2x6	3x6	4x6	3x10
M-L Tilt	----	----	2x6	3x6	4x6	3x10
CW/CCW Rotations	----	----	1x10 each direction	1x15 each direction	2x10 each direction	2x15 each direction

SL= Single Leg; EO= Eyes Open; EC= Eyes Closed; A-P= Anterior to posterior; M-L= Medial to lateral; CW= Clockwise; CW= Counter Clockwise

Compensation or Incentives

Participants received $25 upon completion of the study requirements. No other outside incentives were offered other than any improvements in balance ability that occurred as a result of participating in the study.

Statistical Analysis

Statistical analyses was performed utilizing a mixed design two-factor [treatment groups (2) x time point (2)] ANOVA to analyze the dependent variables related to balance. Mauchly's test was used to determine sphericity. Significant differences in mean values for main effects or interactions were determined using paired t-tests. All statistical procedures were performed using SPSS 17 software (SPSS Inc., Chicago, IL) and a probability level of <0.05 was adopted throughout.

CHAPTER FOUR

Results

Demographic Information

A total of 24 participants were recruited for study participation. Between familiarization and the first training session, six participants declined participation due to inability to make the time commitment needed for participation in the study and/or an occurrence of injury from outside activities. From initiation of training to the close of the 6-week training period, three subjects withdrew, leaving a total of 12 individuals (8 female, 4 male) in the aquatic group and 6 individuals (4 female, 2 male) in the land group who completed all 18 training sessions as well as pre- and post-testing. The demographic information for each group is presented in Table 2. A one-way analysis of variance revealed no significant difference among the demographic data between groups for age (p=.233), height (p=.671), and weight (p=.237).

Table 2

Means and Standard Deviations for Land and Aquatic Group Age, Height, and Weight

Demographic Measure	Land Group (n = 12)	Aquatic Group (n=6)
Age	19.5 ± 1.51	21.08 ± 2.91
Height (inches)	65.58 ± 4.0	66.21 ± 2.21
Weight (pounds)	154.0 ± 22.67	143.45 ± 12.97

**Note*: No significant differences in demographic data existed between groups

Unilateral Stance

Each subject completed the US test prior to and following 6 weeks of balance training in their respective environments. The resultant means and standard deviations of the COP sway velocity obtained during the four conditions (eyes open and eyes closed for both right and left foot) are presented in Table 3 and graphically depicted in Figures 1-4. A significant time effect for the eyes open left foot condition was found (F=5.688, p=.030, η_p^2= .262) and subsequent pair-wise comparison revealed a significant decrease in COP Sway Velocity for the land group (p = 013). Between group effects for left foot eyes open were not significant (F=.374, p=.549, η_p^2=.023). No other conditions associated with the US test revealed significant time or between group effects (Left foot eyes closed: F =.037, p= .851, η_p^2= .002; Right foot eyes open: F=.054, p=.820, η_p^2=.003; Right foot eyes closed: F=.201, p=.660, η_p^2=.012).

Table 3

Means and Standard Deviations for Land and Aquatic Group COP Sway Velocity during the US Test

Condition	Land Group		Aquatic Group	
	Pretest	Posttest	Pretest	Posttest
Eyes Open—left	.855 ± .157	.661 ± .118*	.783 ± .152	.817 ± .163
Eyes Open—right	.828 ± .078	.772 ± .083	.800 ± .148	.828 ± .161
Eyes Closed—left	1.822 ± .381	1.817 ± .326	1.818 ± .498	1.764 ± .367
Eyes Closed—right	1.80 ± .449	1.776 ± .237	1.744 ± .482	1.653 ± .491

* indicates significant difference for time

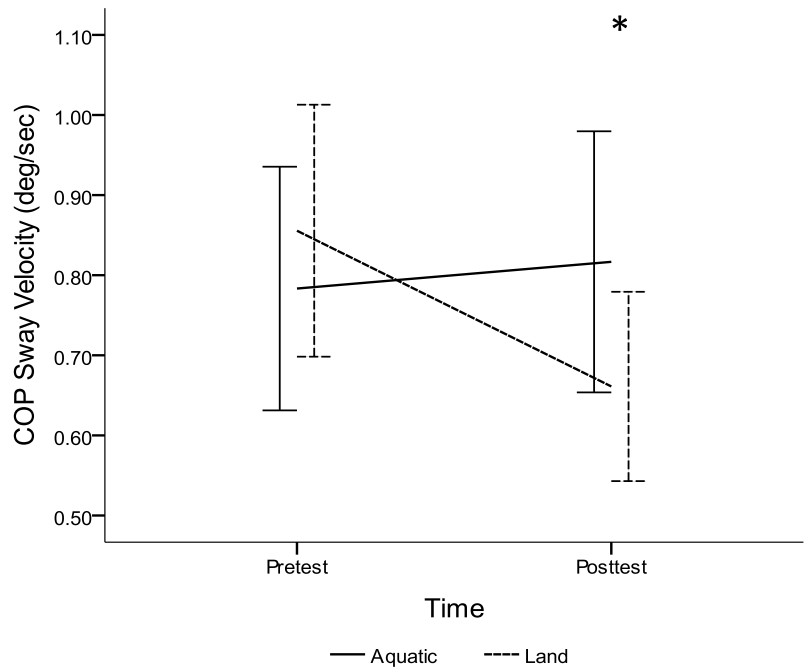

Figure 1. Means and standard deviations for US test COP sway velocity in the eyes open left foot condition. *A significant time effect was found for the land group (p = .013).

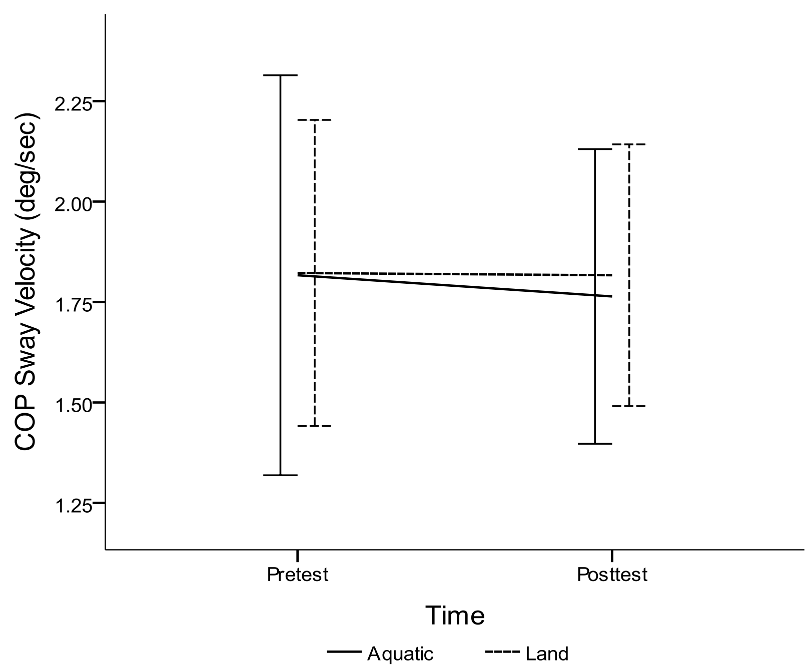

Figure 2. Means and standard deviations for US test COP sway velocity in the eyes closed left foot condition. No significant time or group effects were found.

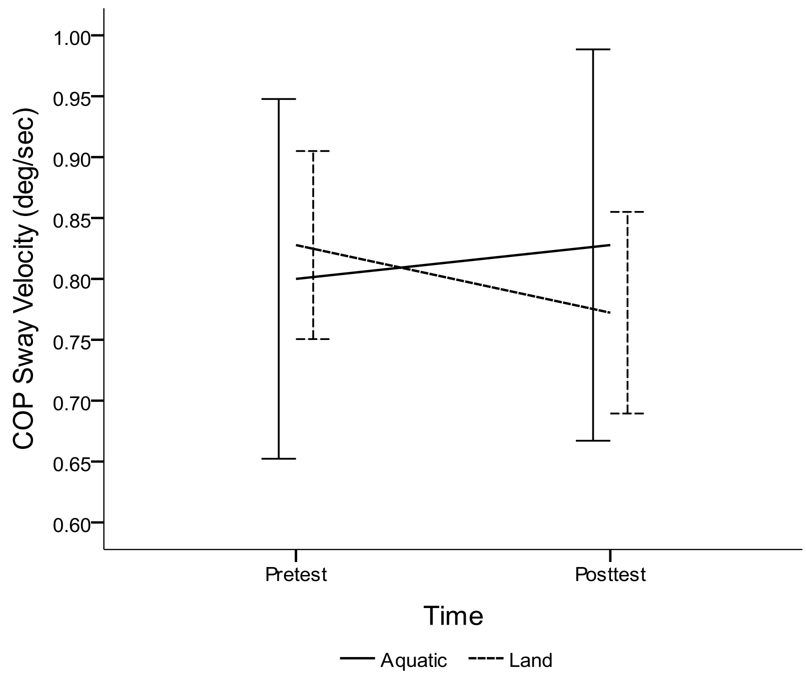

Figure 3. Means and standard deviations for Unilateral Stance COP sway velocity in the eyes open right foot condition. No significant time or group effects were found.

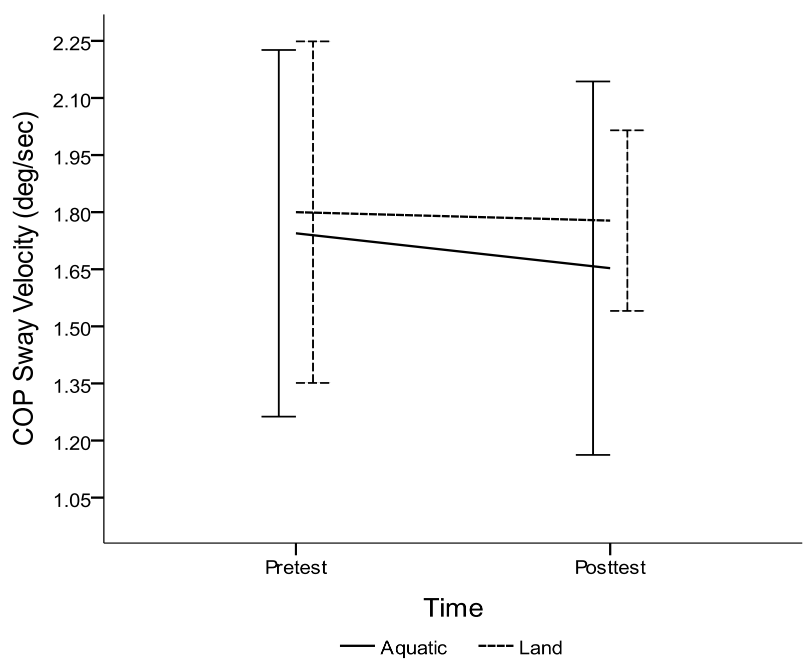

Figure 4. Means and standard deviations for Unilateral Stance COP sway velocity in the eyes closed right foot condition. No significant time or group effects were found.

Hypothesis 1 (H_o1) stated that there will be no statistically significant difference in the US test between the aquatic and land based training groups. As there were no differences in COP sway velocity in any of the unilateral testing conditions, H_o1 was failed to be rejected.

Limits of Stability

Each subject completed the LOS test prior to and following the six week balance training protocol in their group's respective environment. The resultant means and standard deviations for reaction time, movement velocity, maximum excursion, and directional control as obtained during the LOS test are presented in Table 4 and graphically depicted in Figures 5-8. A significant time x group interaction was present for maximum excursion ($F=1.246$, $p=.033$, $\eta_p^2=.254$). Subsequent pair-wise comparison revealed a significant increase in maximum excursion in the aquatic group ($p=.003$), but no significance was found for the land group. Other findings for the LOS test were also not significant: reaction time ($F=2.216$, $p=.156$, $\eta_p^2= .122$); movement velocity ($F=.652$, $p=.431$, $\eta_p^2=.039$); maximum excursion ($F=.733$, $p=.405$, $\eta_p^2=.044$); directional control ($F=2.445$, $p=.137$, $\eta_p^2=.133$).

Table 4

Means and Standard Deviations for land and Aquatic Group LOS Test Outcomes

Condition	Land Group		Aquatic Group	
	Pretest	Posttest	Pretest	Posttest
Reaction Time (sec)	.748 ± .249	.743 ± .20	.625 ± .21	.601 ± .141
Movement Velocity (°/sec)	5.86 ± 2.90	6.06 ± 2.71	6.35 ± 1.50	7.09 ± 1.43
Maximum Excursion (%)	98.97 ± 5.09	97.73 ± 4.63	94.44 ± 6.41	97.69 ± 5.23*
Directional Control (%)	79.15 ± 7.13	77.58 ± 8.47	74.45 ± 3.90	73.96 ± 4.92

^ indicates significance difference for time; * indicates significance difference between groups

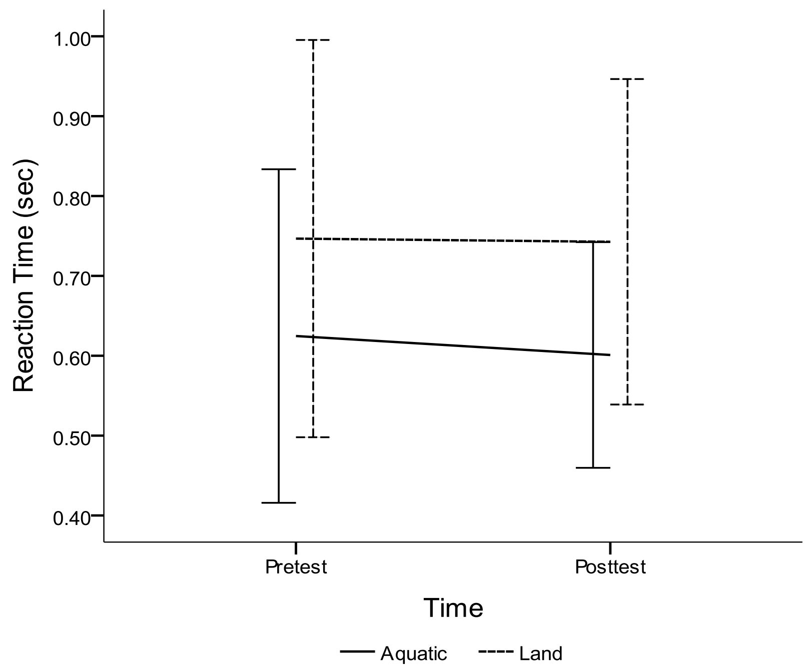

Figure 5. Mean and standard deviations of land and aquatic group measures of reaction time during the LOS test. No significant effects for time or group were found.

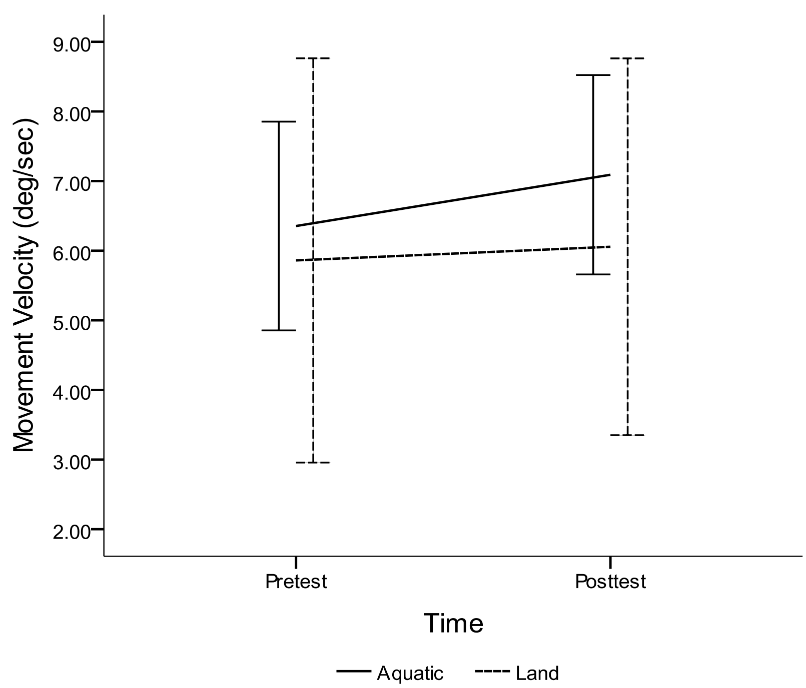

Figure 6. Mean and standard deviations of land and aquatic group measures of movement velocity during the LOS test. No significant effects for time or group were found.

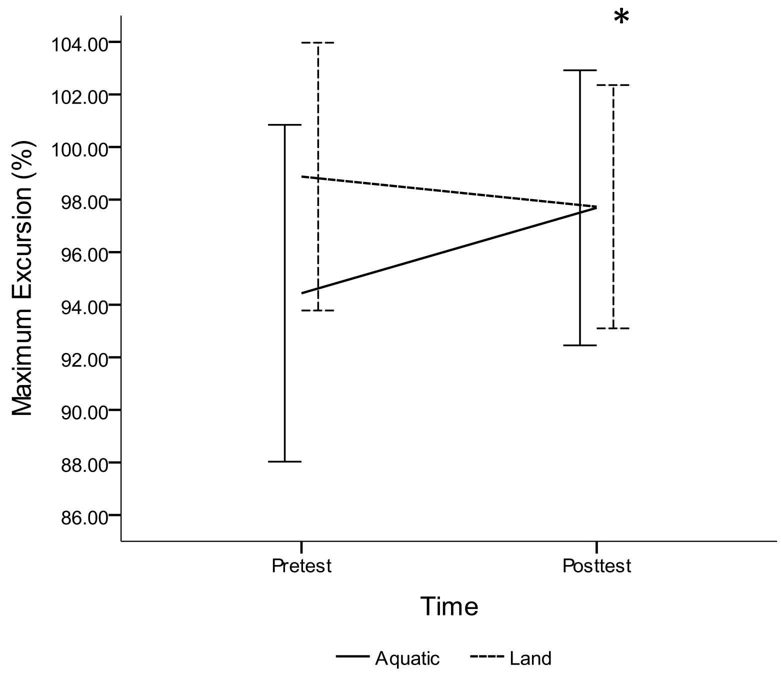

Figure 7. Mean and standard deviations of land and aquatic group measures of maximum excursion during the LOS test. *A significant time effect was found for the aquatic group (p=.003).

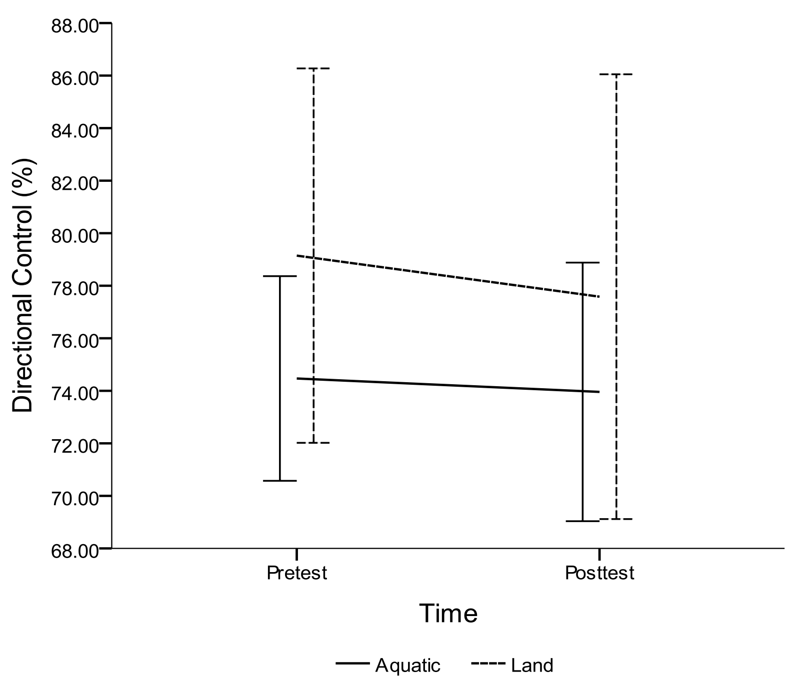

Figure 8. Mean and standard deviations of the land and aquatic group measures of directional control during the LOS test. No significant effects for time or group were found.

Sensory Organization Test

Each subject completed the SOT prior to and following the six week balance training protocol in their group's respective environment. The equilibrium score, as obtained during pre- and posttest SOT, are presented in Table 5 and graphically depicted in Figure 9.

Table 5

Means and Standard Deviations for the Land and Aquatic Group Equilibrium Score during the Sensory Organization Test

	Land Group		Aquatic Group	
	Pretest	Posttest	Pretest	Posttest
Equilibrium Score	83.00 ± 3.41	84. 67 ± 5.61	83.00 ± 6.54	84.83 ± 3.79

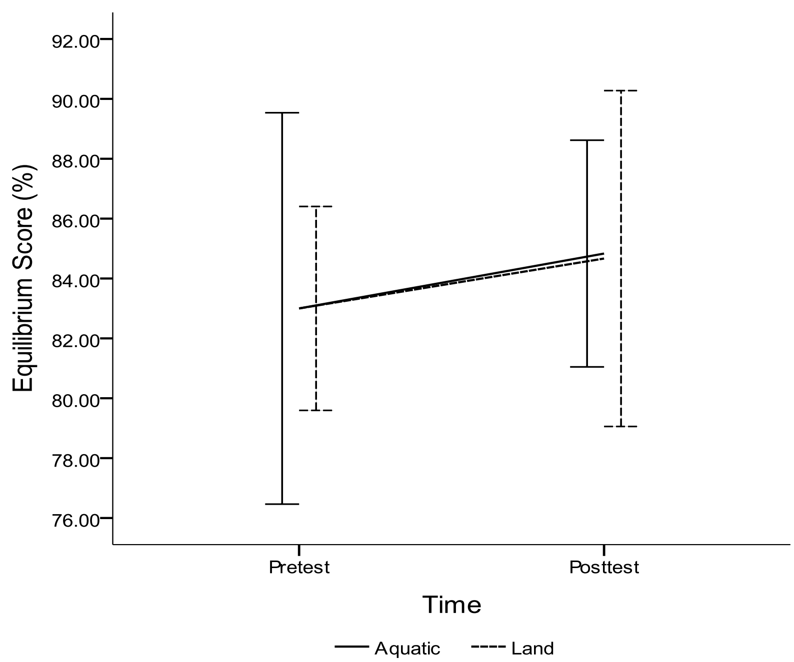

Figure 9. Means and standard deviations for land and aquatic group measures of equilibrium score during the SOT. No significant effects for time or group were found.

A trend toward a significant time effect was found ($F=4.331$, $p=.054$ $\eta_p^2=.213$), however subsequent pair-wise comparison revealed no significant differences between pretest and posttest scores for either balance group. No significance was found for between groups ($F=.001$, p-.973, $\eta_p^2=.000$).

Hypothesis 3 (H_o3) stated that there would be no statistically significant difference in the Sensory Organization Test between the aquatic and land based training groups. No differences in the Equilibrium Scores between groups were present. Thus, H_o3 was failed to be rejected.

CHAPTER FIVE

Discussion and Conclusions

Discussion

The purpose of this study was to determine if aquatic and land-based environments used with identical balance training programs would create significant differences in the outcomes of static and dynamic test batteries. It was hypothesized that no differences would exist between the land and aquatic balance training groups after a 6-week training period. The results of the mixed ANOVA demonstrated no significant differences between groups and only two main effects for time. In the left foot eyes open condition of the Unilateral Stance test, the land group had a significant decrease in COP sway velocity while the aquatic group did not, and in the Limits of Stability test, the aquatic group had a significant increase in maximum excursion while the land group did not. There was also a trend toward a significant time effect for the Sensory Organization Test. These findings did not, however, lead to a rejection of the null hypotheses. Had there been an adequate sample size and an equal number of subjects in each group, these findings might have shown greater differences and other tests may have been significant. Also, because a control group was not included as part of this study due to recruitment difficulties, the improvements that the aquatic and land groups made could not be compared to a non-balance trained population. Thus, it is unknown whether or not their improvements might have been significantly greater than those that would have been experienced by a control group.

Explanations for the significant results that were found relate mostly to the environment in which each improvement was seen. First of all, the significant improvements found for the land group in the eyes open left foot condition of the US test could be explained by the fact that this group were full weight bearing during the balance training program, so more stress was placed on the joint capsules, ligaments, tendons, and muscles of the lower extremity potentially leading to greater improvements in balance. Also, as 17 of 18 subjects in this study self-reported right foot dominance, it is possible that there was a greater deficit in postural control in the left foot that lead to greater improvements in balance scores after the 6-week balance training protocol. Secondly, in reference to the significant improvements seen in the LOS test measures of maximum excursion for the aquatic group, it is possible that the aquatic environment lead to a decreased fear of falling in the participants of that group. This decreased fear could allow these participants to reach further out of their base of support during the balance exercises, thus leading to the improvement in maximum excursion during the LOS test.

These results are contradictory to those found by Roth et al. (2004) in their study comparing land and aquatic training environments over a 4-week period. Using force plate measurements of anterior-to-posterior sway range, medial-to-lateral sway range, and the radial area of COP during single leg standing and tandem stance with eyes open and eyes closed, they found an improvement in balance scores over time for both groups as well as greater improvements in scores for the aquatic group as compared to the land and control groups. Although testing methods are somewhat alike, several dissimilarities between the present study and the study by Roth et al. exist and could possibly explain the different findings. The small sample size and uneven groups in this study present a considerable weakness to its statistical strength, thus increasing the likelihood of a type II error. Also, the subjects within the Roth et al. study were not classified as active individuals. No inclusion criteria were used to ensure subjects did not lead sedentary lifestyles. Thus, the healthy and recreationally active subjects in the present study may not have had as much room for improvement in balance ability.

Unlike the present study, research has shown short term balance training to improve the proprioceptive abilities of healthy active individuals. Rasool & George (2007) used thirty male athletes of an age similar to those used in the present study to demonstrate the effectiveness of single-leg dynamic balance training. The authors found a significant improvement in scores of the Star Excursion Balance Test for the intervention group when compared to a control group after 2 and 4 weeks of balance training. However, the frequency and duration used for the exercises in this study were somewhat different. Their subjects performed a single leg stance similar to that in the study being discussed, but they performed five trials of 1-minute stances daily (as compared to 3 trials, 3 times a week in the present study). It should also be understood when comparing the present study and that by Rasool et al. that the testing methods used are somewhat different. Their method of testing via the Star Excursion Balance Test (SEBT) does not measure the extremes of postural control via center of pressure using a force plate but rather it measures the distance one can reach with the non-weightbearing foot in 5 directions, each 45 degrees apart. The test most like the SEBT used during our study was the LOS test. The biggest difference between the LOS and the SEBT is the fact that the LOS is a two-legged test while the SEBT is a single-legged test. Had subjects performed the LOS on one leg rather than two, the outcome may have proven to be different because the entirety of the balance training exercises used were single-leg exercises. Also, the SEBT does not necessarily measure the distance one can lean outside of his or her base of support while maintaining balance. Instead, one can employ a variety of techniques, including flexing at the knee and hip, to increase reach distance with the non-weightbearing foot. The LOS, on the other hand, requires subjects to rely more on movements at the ankle and less on those at the hip and knee, more accurately measuring the degree of center of gravity displacement an individual can withstand before falling. Therefore, it is difficult to say that the results of the Rasool et al. study can be compared accurately to those found in the present study.

The results of our study may also be differentiated from other studies whose subjects are recovering from musculoskeletal injury. When injury to a ligament, muscle, tendon, or other musculoskeletal connective tissue occurs, a sequelae of inhibitory mechanisms occur leading to potential disruptions in muscle firing and neuromuscular control (Vathrakokilis et al., 2008). Injury also leads to decreased muscle strength and mass (atrophy) which can have a significant impact on one's postural control. In a study by Ribeiro, Teixeira, Brochado, & Oliveira in 2009 that evaluated the effects of a 6-week strength training program for the plantar and dorsiflexors on muscle strength, balance, and functional mobility in elderly individuals, it was shown that a significant correlation exists between increases in plantar flexor strength and balance ability. While strength was not examined in the present study, the influence that balance training has on one's balance ability could explain why greater improvements were not found in healthy individuals who did not have plantar- or dorsiflexor strength deficits. When injury occurs, muscle inhibition often leads to atrophy and subsequent decreases in strength.

Thus, those studies evaluating the effect of balance training on the balance abilities in injured individuals may not be solely influenced by their respective balance programs, but rather a combination of the influences of their programs, natural injury healing, and the strength gains that accompany both.

Another element of this study to be noted is the balance program that was utilized for the 6-week training period. While it was not identical to any other programs utilized in any studies showing an improvement over time, it was formulated based on the progressions and exercises used by them. A large portion of the balance program was formulated on the Roth et al. program. This study used single leg stance on a firm surface, step ups on an aerobic step, a balance and reach exercise similar to the anterior direction of the Star Excursion Balance Test, and several wobble board exercises including anterior-to-posterior tilts, medial-to-lateral tilts, clockwise and counterclockwise rotations. Four of the five exercises used by Roth et al. were also used similarly by Rozzi et al. in their study evaluating the effects of a 4-week balance protocol on individuals with functionally unstable ankles. However, Rozzi et al. used the Biodex Stability System for their balance exercises. The Biodex Stability System is a commercially available dynamic postural stability assessment and training system that consists of a movable balance platform that provides up to 20 degrees of surface tilt in a 360 degree range (Rozzi et al., 1999). Given the similarities this program and equipment had to the wobble board, it was deemed appropriate to use similar exercises for our program. The progressions used were based on those typically seen in a rehabilitation setting and the fact that the individuals in the study were recreationally active and healthy made it necessary to increase the level of difficulty of the programs used in the previously mentioned study.

It should be noted that the balance exercises used in this study were all single-leg exercises while two of the three balance tests used for postural assessment were two-legged tests. Balance scores may not have improved over time for either group because of the differences between the tests and the nature of the exercises used. Even though single leg stance on a firm surface was used, it was used only for the first two weeks of the balance program. Also, once the wobble board was introduced at week three, single leg stance became a dynamic rather than static exercise, as were the rest of the balance exercises in the program excluding the balance and reach test. Thus, the single-leg balance training that was performed may not have improved static single-leg stance. Also of note is the inability of participants to progress to eyes closed conditions on the wobble board. Since subjects were not progressed to the next phase of training if they had to contact the ground with the non-weightbearing foot more than three times during any 30 second trial, some exercise conditions were not practiced as much. While the entire aquatic group was able to progress to single-leg stance with eyes closed, the land group was unable to do so successfully. Also, neither group was able to perform single-leg squats or a single-leg stance with a leg swing with their eyes closed. The inability of subjects to train with their vision eliminated may explain the lack of improvement in the eyes closed conditions of the Unilateral Stance test. For future research endeavors using balance assessments similar to those used in this study, it may be beneficial to include double-leg standing on the wobble board and to continue static single-leg stance exercises with eyes open and eyes closed throughout the duration of the balance training period.

Aside from those explanations previously mentioned regarding uneven grouping, small sample size, difference of subject activity status, and differences among balance assessments, certain other aspects of the present study may have affected outcomes. The subjects in the aquatic group performed balance exercises with the water level approaching the xyphoid process, which allows for an approximate 50% reduction in body weight (Harrison et al., 1992). This depth of submersion may have been too great or too small to induce the desired physiological effects of an aquatic environment. Depth of submersion was not mentioned in the Roth et al. study for comparison. Also, subjects in the aquatic group were not instructed to keep their arms above the water level. This allowed them to use the resistance of the water to maintain balance and may have decreased their reliance on ligamentous and muscular somatosensory input of the lower extremity, leading to less neuromuscular adaptations and the lack of improvement on posttest balance scores. Future research that implements a requirement of subjects to keep arms above the water's surface may find it creates greater balance improvements.

It may also be suggested that the fact that the aquatic group trained barefoot while the land group trained in shoes may have created differing influences of balance training on their respective balance abilities. However, this idea has been tested and disproven in previous research. Whitney and Wrisley (2004) performed a study to determine if timed balance scores on the modified clinical test of sensory interaction and balance (mCTSIB) were affected by shoe wear in patients with balance and vestibular disorders. They found no difference between scores of the mCTSIB with shoes on versus shoes off. While this study does not demonstrate the effects of footwear use during a prolonged balance training protocol, its results can lead one to believe that significant differences will not exist because there were no significant differences between balance ability in the shoed and non-shoed conditions. It can only be assumed that these effects will be applied throughout the balance training period as well. More research is necessary to determine the true effects of balance training while using varying types of footwear, or no footwear, on the outcomes of balance tests such as those used in the present study.

Despite the lack of improvement in balance scores in the intervention groups in the present study, balance training has shown to significantly affect balance ability. The results of this study should not be interpreted to negate that fact. As previously mentioned, balance training not only appears to improve balance ability in healthy and unhealthy populations, it also can aid in decreasing the risk of injury when performed prophylactically. Emery et al. (2005), McKeon & Hertel (2008), McGuine & Keene (2006), Malliou et al. (2004), each have reported positive effects of balance training on the rate of ankle and knee injuries among athletes. McKeon & Hertel (2008), for instance, performed a meta-analysis of several studies on the effects of preventative balance training and found a 20% to 60% reduced risk for sustaining a lateral ankle sprain and a 54% to 74% relative reduced risk of sustaining recurrent ankle sprains after undergoing balance training following an acute ankle sprain. This not only shows the ability of balance training to decrease injury risk but also its effectiveness during rehabilitation of previous injuries to prevent re-injury. McGuine & Keene (2006) found similar results in a study of 765 high school soccer and basketball players. These findings are important with regard to the findings of the current study in that the lack of significant improvement in balance should not be generalized to all balance training. In fact, it has been shown to be a valuable tool in preventing and rehabilitating injuries seen across the lifespan, and should continue to be seen as such.

Future Direction

As previously mentioned, several factors that could have affected the outcome of the present study should be taken into account in future research. First of all, research needs to be done to determine which balance tests are most applicable to given populations and how well different types of tests correlate to one another. Once a "gold standard" method of balance testing is agreed upon for different populations, it will be much easier to compare what influences different balance programs, training environments, and population types have on balance ability. The balance tests and balance training exercises should be more compatible with one another so that improvements in balance that occur due to training will be seen via balance testing. Also, when incorporating an aquatic environment, better regulation should be placed upon the manner in which balance exercises are performed and what mechanisms participants use to maintain balance during immersion. It may also be beneficial to incorporate measures of strength gain into the pre- and post testing sessions to determine the extent that plantar and dorsiflexor strength plays in balance ability and whether or not deficits can be reversed with aquatic balance training. Given that the only research known to exist presently has been performed on healthy individuals, it is also essential that future research be performed using subjects that are recovering from injury.

Conclusions

The results of the present study did not reveal any significant differences between land and aquatic balance training nor did it reveal any significant differences between pre- and post testing sessions. This lack of improvement in balance scores is discouraging, but should not negate the findings of previous research. Balance training is a valuable tool in injury prevention and rehabilitation and should continue to be incorporated in clinical practice when indicated. More research needs to be performed to determine the true influence of an aquatic environment on balance ability, but given the beneficial physiological effects this environment has had in previous research, it is still recommended for use in situations where land-based exercise might be contraindicated.

APPENDICES

APPENDIX A

Recruitment Flyer

Researchers at **Baylor University** in the Department of Health, Human Performance, and Recreation are recruiting 30-40 healthy, ***moderately active (exercise at least 3 times a week)*** men and women ***18-35*** years old to participate in a study designed to evaluate the effects of different balance training environments on balance ability.

FREE BALANCE ASSESSMENT!!!
FREE FITNESS ASSESSMENT!!!!
SUPERVISED TRAINING!!!!

Do you want to improve your balance?

For more information call:
Shellie Spiers, ATC, LAT;
Shellie_Spiers@baylor.edu; (cell) 318-455-4637
Rena Marrs McLean Gymnasium Room 117

Subjects will be required to follow a supervised balance training program and participate in testing sessions during the ***6 week*** *training period.*

Eligible subjects will receive $25 upon completion of the training program

BAYLOR
UNIVERSITY
ESNL

APPENDIX B

Baylor University
Dept of HHPR
Medical History Questionnaire

Directions. The purpose of this questionnaire is to enable the researchers to evaluate your health and activity status. Please answer the following questions to the best of your knowledge. All information given is CONFIDENTIAL as described in the Informed Consent Statement.

Name: ____ Age _____Date of Birth_______________

MEDICAL HISTORY

1. If you have a prior history of unresolved pain, injury or surgery to any of the following body parts, please place a check by any that apply.

☐ Foot
☐ Ankle
☐ Leg
☐ Knee
☐ Thigh
☐ Hip
☐ Pelvis
☐ Back/spine
☐ Neck/spine
☐ Head/brain

Please provide information regarding the type and extent of the injury or injuries that you checked.
____
____

2. Are you currently taking prescription or over-the-counter medication for pain or inflammation?
YES_____NO_____
If yes, what medication(s) are you taking? ____

3. Are you currently taking or have taken within the last 3 months any nutritional supplement except for multivitamins? YES _____ NO_____
If yes, please explain ____

4. Do you currently have an active inner ear infection? YES_____ NO_____

5. Do you have any other condition that may affect your balance? YES_____ NO_____
If yes, please explain ____

6. Do you have a fear of the water that would not allow you to participate in an aquatic exercise program where you will be standing in water up to your chest? YES_____ NO_____

Recommendation for Participation

____ No exclusion criteria presented. Subject is *cleared* to participate in the study.
____ Exclusion criteria is/are present. Subject is *not cleared* to participate in the study.

Signed: ___________________________________ Date: ________________________

APPENDIX C

Baylor University
Exercise and Sport Nutrition Laboratory
Exercise & Supplement History Questionnaire

Personal Information

Name:

Address:

City: ___________________________ State: ______ Zip Code ________

SS#: ___________________________

Home Phone: (___) _____-______ Work Phone: (___) _____-_______

Beeper: (___) _______________ Cellular: (___) _____-_________

Fax: (___) _____________________ Email Address: ____________________

Birth date: _____ / _____ / ______ Age: ______ Height: ______ Weight: ______

Leg Dominance: R____ L ____ (Which leg would you use to kick a ball?)

1. Describe your typical occupational activities.

2. Describe your typical recreational activities

3. Describe any exercise training that you routinely participate.

4. How many days per week do you exercise/participate in these activities?

5. How many hours per week do you train?

6. How long (years/months) have you been consistently training?

7. When was the last time you ingested an anti-inflammatory product?

8. What was the reason you were taking an anti-inflammatory product?

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