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Title: A Comparison of Two Different Balance Programs

Abstract approved:

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There is limited knowledge regarding differential training as it relates to balance. The purpose of this study was to compare the performance and retention of a differential training balance program and a traditional balance program. Thirty-three Division I soccer athletes volunteered to participate and 29 completed the study. Participants were assigned into either a differential training program or a traditional program. The balance programs were part of the warm-up used before team activities during the non-traditional season. In order to evaluate the effects of the program, static balance was measured via time to boundary (TTB), dynamic balance via time to stabilization (TTS), and agility via the arrowhead agility test. A baseline TTB, TTS and arrowhead agility test was measured before the start of the intervention, then immediately after it ended. Finally, a retention test was done 14 days after the four-week intervention ended. We hypothesized there would be equivocal results between the differential training program and the traditional balance program after the four-week training, but the participants in the differential training group would demonstrate increased retention after two weeks of no training. Although we did find that the differential training had equivocal results to the traditional program, there were no differences in retention on any of the static or dynamic balance measures or agility tests when compared to the traditional program.

A Comparison of Two Different Balance Programs

By
Jordyn Eisenhard

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APPROVED:

Major Professor, representing Exercise and Sport Science

Co-Director of the School of Biological and Population Health Sciences

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Jordyn Eisenhard, Author

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CHAPTER 1 – INTRODUCTION

Ankle injuries are one of the most common sports related injuries and tend to occur in athletes with balance deficits.[2, 3, 12, 25, 41, 45] Previous researchers have reported improvements in static and dynamic balance following balance training in both individuals with stable[1, 11, 21, 29] and unstable ankles.[4, 10, 30] Furthermore, individuals who complete a balance training program are less likely to become injured than those who do not.[25, 42] Therefore, there is a great interest in developing interventions that improve balance and reduce the risk of ankle injuries.

Although existing balance training programs improve balance and reduce injury rates, they are based off of a motor learning theory that posits repeating a task in an “error free” manner is the optimal way to learn a motor skill. These traditional balance programs involve the participants repeating a task (or several tasks) multiple times a week with the goal of an error free performance - such as standing as still as possible on one leg without swaying the trunk or stumbling out of position. Although these programs improve balance, they may not adequately address the way the individual actually acquires and refines motor skills, which is usually through trial and error. Additionally, it is unknown if the gains in performance measured at or near completion of these balance training programs actually are retained for some period of time following the program.

Whereas traditional balance training programs incorporate error free repetition, differential training utilizes an opposite approach by actually incorporating errors and eliminating repetition in the program. This type of training is rooted in dynamical systems theory, which suggests that movements emerge from the interaction of the individual, the environment and the motor task. Specifically, differential training encourages the individual to learn the task by completing it in a variety of ways and positions by performing it with “variations of joints involved, movement geometry, velocity, acceleration, time structure and rhythm, variations of classical movement errors, variations of equipment and environment and combinations of all variations without any movement repetition”[33]. This approach is hypothesized to allow the individual to better understand the relationship of the body, the environment and the task and ultimately be more prepared to adapt to changing constraints during the movement. Previous researchers have compared differential training to traditional, error free, heavy repetition training for motor tasks such as hurdling, high jumping and tennis serving[34, 35, 36, 37]. The findings of these studies are interesting because while they have reported equivocal results on performance tests immediately following completion of the training, the differential groups demonstrate greater retention on performance of the skill[34, 36, 37]. To our knowledge, differential training has never been applied to balance, but it is logical that balance training, particularly for injury prevention in sport, it might benefit from differential training, as it incorporates changing the environment and task and possibly leads to greater retention compared to traditional training programs.

Therefore, the aim of this study was to compare a traditional balance training program with a balance program that incorporated the principles of differential training in college soccer players. The main outcome measures were static and dynamic balance. Static balance is defined as an individual's ability to maintain the body in a position of static equilibrium[15, 26]. Time-to-boundary was used to assess static balance. To calculate time to boundary, the foot is modeled as a rectangle. The distance between the center of pressure (COP) in the medial/lateral (ML) direction to the medial and lateral borders of the foot is calculated. If the COP is moving medially, the distance between the COP and the medial border of the foot is calculated and then divided by the ML COP instantaneous velocity. This value represents how long it would take the ML COP to reach the medial border of the foot if it were to continue moving in the same direction without a change in velocity. If the COP is moving laterally, the distance between the COP and the lateral border of the foot is calculated then divided by the ML COP instantaneous velocity. The same procedures were repeated in the anterior/posterior (AP) direction[20]. Three specific outcome measures are reported when using time to boundary: absolute minimum, mean of minima, and standard deviation of the minima. Absolute minimum and mean of the minima represent how long it takes an individual to make postural corrections. Standard deviation of the minima represents the amount of solutions an individual used when correcting their postural control.

Dynamic balance, the ability to maintain equilibrium while performing a functional movement, was evaluated by time to stabilization (TTS)[27]. TTS measures how quickly the individual can stabilize the anterior/posterior (AP), medial/lateral (ML), and vertical ground reaction force (GRF) following a jump. A composite of all three directions was also calculated to create a global TTS measurement for each individual, which allows for an understanding of an individual's postural control.

Additionally, the Arrowhead Agility Test (AAT) was measured. While an agility test is not specifically a measure of balance, agility inherently requires the use of balance in order to maintain body control while changing directions. Although the AAT has not been cited in the literature, it is commonly used in the athletic population.

Both of the balance training programs were four weeks in duration, with a pre-test prior to the intervention, a post-test after the conclusion of the intervention, and a retention test 2 weeks after the post-test. The goal of this research was to see if differential training improves retention of balance performance to help inform clinicians and coaches on which balance training program should be used clinically based on balance and agility outcomes.

CHAPTER 2 - LITERATURE REVIEW

Ankle injuries are one of the most common sports related injuries[2, 3, 12, 45]. Not only can ankle injuries result in time lost from sports participation, ankle injuries can lead to long term pain and discomfort[5, 14]. Medical costs for ankle injuries were estimated to be $70 million dollars in 2003[41]. Due to the high costs of ankle injuries and the potential for long-term disability, it is crucial to find a method to reduce the risk of ankle injuries.

Individuals with an increased balance deficit have been shown to have increased risk for ankle injuries[11, 25, 42]. In a review of sixteen articles, Distefeno et. al. found that balance can be improved in the healthy population and suggested that balance programs be included in injury prevention programs[10]. Not only has balance been investigated in the healthy population, but it has also been studied in those with CAI. This unstable population is characterized by complaints of frequent bouts of their ankle giving away during functional activity[16]. Research has demonstrated that balance can be increased in the CAI population via balance training programs[4, 10, 30].

These balance training programs are created from the traditional view of motor learning, where learning is believed to be achieved through error-free movement. Even though these balance programs have been shown to increase balance (thereby decreasing ankle injury), they promote repetition of the same tasks with no errors. On the other hand, dynamical systems theory addresses the idea that errors and variability are essential to motor learning. Differential training programs, which are based of the dynamical systems theory, encourage individuals to perform erroneous and random movements with no repetition while learning a motor skill[36]. Individuals who have learned other motor skills via differential training have been shown to learn the skill to the same extent as the traditional group but better retain the skill in the long term[34]. While differential training has been studied with other motor skills, it has yet to be investigated with balance training.

Balance

Balance is commonly defined as keeping one's center of mass within the base of support or maintaining the moments of the individual's center of mass in equilibrium[15]. In order to accomplish this, sensory information from the somatosensory, vestibular and visual systems are integrated[17]. All afferent signals from the somatosensory, vestibular and visual systems come together in the central nervous system (CNS), where they are interpreted and combined to give an idea of where the body is in the environment.

The CNS does not rely on a single system; rather it takes information from all three systems, and combines all the information. An interruption to any of these three systems could lead to a decrease in balance and possibly injury.

There are two different types of balance: static and dynamic. Static balance is defined as one's ability to maintain the body in a position of static equilibrium or not move the body outside its base of support[15, 26]. Dynamic balance is defined as the ability to maintain equilibrium while performing a functional movement[27]. There are different ways to measure balance used.

Static balance is typically assessed during a single leg stance by measuring the center of pressure (COP) movement while standing on a force plate. Overall, excursion and velocity are two of the most common COP variables investigated. Less COP displacement and slower velocity are associated with better balance[20]. Although COP displacement and velocity are commonly measured when investigating postural control, there is a more sensitive measure of static balance[20].

Time to boundary (TTB) also incorporates COP measurements, but it allows for a more in-depth examination of the COP movement. TTB is calculated by having the participant perform a single leg stance. The stance foot is modeled as a rectangle and the COP is traced in both the anterior/posterior and medial/lateral direction separately. For each COP point, the distance is calculated from the border of the foot/base of support as well as the position and instantaneous velocity of the COP. The data is then used to estimate the time it would take for the COP to reach the edge of the base of support[20]. A lower TTB correlates with greater postural instability[41]. TTB gives greater insight on postural control because it not only examines how quickly the COP is moving, but also where in the foot the COP is moving.

Three specific outcome measures are reported when using time to boundary: absolute minimum, mean of minima, and standard deviation of the minima. Absolute minimum and mean of the minima represent how long it takes an individual to make postural corrections. Standard deviation of the minima represents the amount of solutions an individual used when correcting their postural control[20].

Researchers have found that there are significant differences in TTB measures between those with CAI and those with stable ankles that were not picked up by traditional COP measurements[20]. When comparing traditional COP measures (velocity and displacement) to TTB measures, pearson product moment correlations ranged between 0.3 - 0.9, with the standard deviation of TTB minima to be the most weakly correlated[20]. This demonstrates that TTB measures are measuring something different that traditional measures are not.

Although static balance provides insight into postural control, it does not address how balance is maintained during functional movements. Dynamic balance measures allow for observation of postural control during a functional activity. Time to stabilization (TTS) is a widely used measurement of dynamic balance. This procedure measures the amount of time it takes to stabilize balance after landing from a jump movement.

TTS is determined first by measuring the individual's maximum double-leg vertical jump height using a Vertec device. The person then stands 70 cm from the center of the force plate and is instructed to perform a double legged jump to 50% of their maximum vertical jump height and land on one leg on the force plate. The participant is instructed to maintain stability on the single leg for 20 seconds after landing from the jump.

TTS measures how quickly the individual can stabilize the anterior/posterior (AP), medial/lateral (ML), and vertical ground reaction force (GRF) following a jump. A composite of all three directions was also calculated to create a global TTS measurement for each individual. Forces are normalized to body mass, so fluctuations around the AP and ML axes are about 0 and fluctuations around the vertical axis are 1. The first three seconds after initial ground contact (defined as > 10 N of vertical GRF) are analyzed. Unit-less stability index scores are calculated for AP (APSI), ML (MLSI) and vertical (VSI) directions (see Figure 5)[43]. A composite score (DPSI) of the APSI, MLSI and VSI is calculated as well. By studying a landing technique, it gives insight into how individuals stabilize their ankle in functional movement, which is when ankle sprains most commonly occur.

It has been shown that those with Functional Ankle Instability (FAI) have a longer TTS, meaning that they have decreased dynamic balance (Individuals that suffer from FAI and CAI both have chronic giving out of the ankle joint, but the main difference is that those with CAI have mechanical instability on top of the neuromuscular and/or strength deficits[6, 28]). In one study, 20 healthy subjects were compared to 20 subjects with FAI. In this study, participants were asked to land in a double leg stance (rather than a single leg stance). After comparing traditional measures (COP excursion length, velocity and area) to TTS measures, results found the FAI group took significantly longer to stabilize in the anterior/posterior direction when compared to the healthy individuals[28]. This study not only demonstrates that TTS is different in individuals with FAI, but it also shows that TTS is more sensitive to balance deficits.

Another study compared 10 healthy subjects and 10 FAI subjects and found that the mean TTS times of seven jump landings were significantly lower for the healthy subjects[28]. Healthy subjects stabilized in 1.45 seconds, with a standard deviation of ± 0.30 seconds, while FAI subjects took 1.98 ± 0.81 seconds to stabilize. Again, the data shows that a lower TTS time is correlated with a stable ankle, and therefore, better postural control.

Balance Training and Balance Improvement

Many different balance training programs have been investigated to fully understand how balance is trained and increased. Studies have shown that balance improves when individuals participate in balance programs.

Balogun et. al. looked at the effect of wobble board training on static balance with both eyes open and closed[1]. Thirty healthy athletes were divided into two groups: a control and intervention group. The intervention group performed wobble board training three times a week for six weeks while the control group did not receive any training. The examiners tested balance by timing how long each participant could hold a single leg stance on their dominant leg without stumbling or putting their other leg down. Balance was tested before training and then again after the six-week program ended. Pre- and post-test data was analyzed and the results showed that the intervention group significantly improved their time in a single leg stance for both eyes open and closed situations while the control group stayed the same.

Hoffman and Payne studied 28 healthy subjects who were randomly placed into two groups: an intervention group and a control group. Both groups had their COP sway variability tested on force plate while holding single leg stance for 20 seconds on their dominant leg. The intervention group trained on the Biomechanical Ankle Platform System (BAPS) board three times a week for 10 weeks while the control group did no additional balance training[21]. After 10 weeks, both groups' postural sway was re-tested. It was found that the intervention group improved their COP sway variability by 0.82 ± 0.95 and 0.50 ± 0.54 for medial/lateral sway and anterior/posterior sway respectively. The control group improved their sway by only 0.15 ± 0.55 and 0.12 ± 0.15 for medial/lateral sway and anterior/posterior sway respectively.

In another study, thirty-two healthy subjects were randomly assigned into four groups: strength training program, balance training program, combination of balance and strength program and a control group[4]. The strength program used Therabands, free weights, and bodyweight in the program to improve lower leg muscle strength. The balance program utilized the BAPS board as well as ankle Theraband exercises for stability and single leg stance balancing. The combination program used exercises from each of the strength and balance programs. The control group did no additional training for the length of the programs. Subjects' balance was measured as postural sway and on the Biodex Stability System both before and after the six-week program. The results revealed a significant improvement in balance for each of the intervention programs but not for the control group and that there was no difference in improvement between the intervention groups.

In another study, Rothermel looked at the effect of single leg stance training and balance. Forty-five healthy subjects were randomly put into one of three groups: a traditional balance program, a balance program that emphasized foot position and a control group[29]. The traditional balance program consisted of training in two visual conditions (eyes open and closed) as well as on foam and hard surfaces with different arm positions all during single leg stances. The foot position group consisted of the same exercises but clinicians were encouraged to elevate the medial longitudinal arch while keeping the rest of the foot on the ground during balance exercises. This position was tested because it was thought it increased cutaneous stimulation in the sole of the foot, and therefore, possibly it provided more afferent information to the central nervous system. The programs were measured three times a week for four weeks. Pre- and post-tests of COP velocity were done for a single leg stance with both eyes open and closed. After the pre- and post-test data were analyzed, the traditional group had significantly greater reductions in COP velocity for both conditions than both the control and the foot position group.

Balance training programs have also been used in individuals with previously injured ankles. For example, Gaufin looked into the effects of ankle disc training on subjects with FAI. There were 10 subjects with FAI that went through eight weeks of training on the ankle disc five times a week[13]. Each training session lasted for 10 minutes and was done on the symptomatic foot. The pre- and post-tests of postural sway, as defined by displacement of the center of pressure, were analyzed and it showed that after the intervention the postural sway had decreased for both the symptomatic and non-symptomatic foot. Center of pressure sway was reduced from 9.0 ± 1.3 mm pre-training to 6.1 ± 1.0 mm post-training. Those without FAI had a COP sway of $7.6 \pm .9$ mm.

Kidgell et. al. compared an ankle disc balance program, a trampoline balance program and a control group in 20 subjects with a history of ankle injury[23]. The subjects in the trampoline and disc groups performed the same balancing tasks on their respective equipment. As the program progressed, both the training volume and load increased. During the first two weeks, participants maintained a single leg stance with eyes opened for 30 seconds three times. In weeks three and four, participants held a single leg stance for 60 seconds three times and also added in 10 repetitions of tilt (anterior/posterior and medial/lateral) exercises. Finally, in weeks five and six, a single leg stance was performed three times for 30 seconds (eyes closed) and the tilt exercises were repeated for six repetitions (eyes closed as well). The interventions were done three times a week for six weeks. All subjects were tested pre- and post-balance program for postural sway. The results showed that the ankle disc training and the trampoline training were equal in their effects and they both significantly reduced postural sway when compared to the control group.

Rozzi et. al. studied the effect of training on the Biodex Stability System on balance. There were 26 subjects total in the study, half with FAI and half with stable ankles. Each group participated in the same balance training program on the Biodex Stability System three times a week for four weeks[30]. Subjects had to focus on the visual feedback screen and keep a cursor at the center of a bulls eye. The bulls eye represented the platform. Subjects also had to actively move the platform in a specified way as dictated by the visual feedback system. The groups were pre- and post-tested for a stability index (SI) measurement. A lower the stability index indicates better balance. After the results were analyzed, the authors concluded balance training was an effective means of improving joint proprioception and single leg standing ability in subjects with unstable and stable ankles. Both groups had significant decreases in their SI after completing the four weeks of balance training.

Based on these results it appears that balance training programs are effective at increasing balance in both healthy individuals and those with CAI. While there are many different types of balance training including ankle discs, wobble boards, and just different single leg stance exercises performed anywhere from four to ten weeks, there does not seem to be a specific method or type of exercise that produces significantly different results.

Balance Training and Injury Risk

Researchers have studied balance programs to determine the possibility of improving balance and/or decreasing ankle injuries. Many studies have found that balance programs improve balance and decrease injury risk[25, 42]. Balance programs can involve a single leg stance on stable surfaces such as the ground or unstable surfaces such as ankle discs, wobble boards and balance boards. Most balance programs show significant changes in injury incidence.

One study looked at the effects of ankle disc training on injuries in athletes[42]. In the study, 237 handball athletes were randomly divided by teams into an intervention group and a control group. The intervention program consisted of single leg stances on an ankle disc for 10 to 15 minutes two times a week each session over the course of a 10-month season. The control group did no additional balance training. The results showed that there was a greater number of ankle injuries in the control group (23 injuries total) compared to that of the intervention group (six injuries total)[42]. The study also showed that the intervention group had significantly fewer non-contact injuries when compared to the control group. This shows that balance and postural control affect injuries to the entire body, not just the ankle joint. Therefore, by increasing balance via training programs, not only can ankle injury incidence decrease, but potentially all types of injury incidence may decrease.

Emery et. al. studied the effect of balance training on a wobble board on balance and self-reported injuries. One hundred and fourteen healthy subjects participating in physical education classes were split into an intervention group and control group. The intervention group trained on the wobble board five times a week for 20 minutes per session for six weeks. The control group received no training and went on with normal athletic activity in their physical education class. Static balance, how long a single leg stance could be maintained, as well as dynamic balance, how long a single leg stance on foam could be maintained, was measured. They found that the intervention group improved in both static and dynamic balance when compared to the control group[11]. The self-report data showed that only two subjects of the intervention group sustained ankle injuries in six months post-training, while 10 subjects in the control group sustained an ankle injury.

McGuine et. al. examined at the relationship between balance board activities and ankle sprain rate. They studied 765 high school soccer and basketball athletes who were randomized by team into an intervention group or a control group. The intervention program consisted of balance board and single leg stance exercises. Functional tasks, such as squats, swinging the non-stance leg or throwing, dribbling or catching a ball, were performed on a hard surface or on the balance board. Visual condition was also varied on both the hard surface and on the balance board. Subjects participated in the balance program for the duration of the five-week season. The researchers found that the rate of ankle sprains was significantly greater in the control group than for the intervention group (the risk of ankle sprain for the intervention group was 62% of that of the control group). When investigating ankle sprains, the researchers grouped them into minor and moderate sprains. Minor ankle sprains were defined as a loss of 1-6 days of athletic participation while moderate sprains were characterized as a loss of 8-21 days. The intervention group had more mild sprains (79% vs 59%) where as the control group had more moderate sprains (22% vs 33%), although these percentages were not significant findings[25].

Literature shows that participation in a balance program leads to reduction of injury, both at the ankle and the rest of the body. By having athletes take part in balance training, injury incidence can be decreased.

Motor Learning Theories

As we continue to study the human body a better understanding of motor skill acquisition has emerged. Early theories of motor learning stated that skills were learned through constant repetition of the same correct movement over and over again. It was believed that as a person repeats a movement, the "movement becomes more coordinated, individual phases are interconnected, leading to a good and refined movement"[8]. The thought was that it took up to 50,000 repetitions of a task to automate it and achieve perfection[8]. Any error that was made in the repetitions was considered erroneous or extraneous noise and was viewed as unnecessary[31]. The theory of repetitions led scientists to the idea of the existence of motor programs.

Motor programs are defined as a task or a movement that is centrally controlled and organized[32]. A motor program encompasses processing time, reaction time and the actual movement itself. It was thought that as one continually repeated the same motor program, they became more efficient and filled with less error. Every single movement was thought to have their own motor program. This meant that even if two different tasks or movements were similar, they would not necessarily carry over to each other[19]. The idea of a methodical approach to motor learning was to break down each movement in a motor program into smaller tasks and repeat those individually[22]. Once each individual movement was correct, and then the person would put all the movements together and create the large movement more efficiently. It was thought that individual movements had to be repeated within 15 minutes of instruction or else error would increase[22]. The problem with this theory was that similar movements do carry over, such as throwing different types of balls or hitting with different kinds of rackets or bats[31, 39].

In order to account for the translation of skill, the schema theory was developed. The idea behind the schema theory is that there are general motor programs for broad tasks such as locomotion, throwing and jumping[31]. Under each general program, there are ‘subprograms’ which account for different speeds, accelerations, objects and other factors. The schema theory also states that practice of skills should be in blocked increments[31]. For example, a certain amount of time you should practice throws from the free throw line and then move to a different area on the court and then move to a inside jump shot. The idea behind the blocked practice was that it allowed for greater variability, which created greater generalization of specification from recall schema and provide for better error detection[39]. The issue with the schema theory is that random practice, rather than blocked practice, has been shown to be more effective in retaining skills. Random practice is defined as mixing in different types of drills or motor skills from trial to trial in one session, rather than fixating on one type of skill than moving on to another over the course of a session.

One way to introduce random practice is through contextual interference. The theory of contextual interference is described as switching from one skill to another or changing the context in which a task is practiced from trial to trial[38]. While the tasks vary within the practice, it does not mean the skills are performed in a random manner. Although it does not instruct performance of random movements before, during and after tasks, it does encourage learning multiple tasks and skills in one session to increase retention and task transfer[38]. The idea is that the processing of the new skill will be more elaborate and distinctive, causing easier retention of the task for the person.

Dynamical systems approach to motor learning suggests that movements are dictated by the interaction between the individual, the environment and the task itself. It also expresses that fluctuations and errors are imperative to the learning process. Differential training is a method of teaching skills that is based on the theory of dynamical systems and focuses on practicing movements with different errors, a person is only preparing themselves for unexpected changes or possible constraints[35, 37, 40]. Variations to movement include "variations of joints involved, movement geometry, velocity, acceleration, time structure and rhythm, variations of classical movement errors, variations of equipment and environment and combinations of all variations without any movement repetition"[37]. The variations allow for individuals to explore their environment and pick up information for future actions or tasks[9].

Differential training has been shown to work in different settings. Schollhorn examined the effects of differential training on high jumping skills. Fifty-seven subjects were randomly split into three groups: a differential training group, a traditional training group and a control group. The differential training group was never given feedback and never repeated the same high jump maneuver once. The traditional training group was trained with feedback after each jump and repeated many of the same jumps. The control group did no jumping. Each of the training groups met twice a week for four weeks. Each group was tested before the intervention, immediately following the intervention and 10 days after the intervention. Although both training groups significantly increased jump and reach height by about two cm immediately following training, only the differential training group maintained the increased jump and reach height after 10 days[34].

In another experiment, the effects of differential training on soccer shooting and passing skills were analyzed. In the study, 16 senior soccer players were broken up into two groups: traditional training and differential training. Both groups went through training 12 times over four weeks. The differential training group practiced with different movements, continuous changes, no repetitions and no feedback. For example, squatting while passing or spinning in a circle after shooting the ball. The traditional training group had a detailed description of how each task, shooting and passing, should be done and repeated those movements. Each group was tested pre- and post-training for accuracy. The results showed that the differential group became more accurate than the traditional group[37].

Another study examined differential training and shot put performance. Subjects were divided into two groups: a traditional training group and a differential learning training group. Researchers measured the distance that the participants were able to throw the shot put before, immediately after training, two weeks after training and four weeks after training. The results showed that the differential training group was able to retain the increases in the average shot put throw during both the retention tests, while the traditional group went back to their initial performance[35].

Overall, it seems that differential training allows for an increased retention in skill when compared to a traditional training program. By adding in errors and being forced to explore the environment, rather than repeating the same movement, retention is increased. In order to find which training program works better for balance acquisition and retention, further research needs to be done.

CHAPTER 3 - MATERIALS AND METHODS

Participants

Thirty-three (14 females, 19.6 ± 1.2 years old, and 19 males 20 ± 1.2 years old) Division I soccer players who were cleared to participate in team activities (i.e., games, practices and conditioning/fitness training) by the team's certified athletic trainer, consented and enrolled to participate in the study that was approved by the University's Institutional Review Board. Four participants were injured during team activities over the course of the study and were removed from the study. One participant did not return for follow up testing and was removed from all data analyses. A total of 28 participants finished the study.

Following consent, participants completed a health history questionnaire to screen for the following exclusion criteria: current vestibular or balance disorders, a concussion within one month prior to enrolling in the study, or were currently undergoing lower extremity rehabilitation.

Following exclusion criteria screening, participants completed the Foot and Ankle Disability Index (FADI) including the Sports' Module prior to any testing to assess for chronic ankle instability (CAI). Scores below 90% on the FADI were categorized as having chronic ankle instability (CAI)[24].

Procedures

In total there were three data collection sessions over the course of the study: a pre-test prior to commencement of the four-week training program, a post-test after the balance training program, and a retention test two weeks after the post-test (see Figure 1). At all of the testing sessions, height (cm), mass (kg), static and dynamic balance, and agility were measured. Additionally at the pre-test, leg dominance - defined as self-reported leg used to kick a penalty kick, dominant foot width and length, and starting level to the traditional balance training program were determined.

Static Balance

Static balance was assessed using time-to-boundary (TTB). TTB estimates how long it would take the COP to reach the boundary of the base of support if the COP were to continue moving a constant velocity on its current path. TTB is calculated by modeling the foot as a rectangle. This is done by measuring the participant's dominant foot when they are standing barefoot on a blank sheet of paper with the posterior and lateral edge of the foot aligned to a 90° wood frame (see Figure 2). Marks were made on the paper at the widest (medial) and longest (anterior) aspects of the foot. The participant then removed the foot and a rectangular model of the foot was created by drawing two perpendicular lines that intersected the marks at the widest and longest aspects of the foot. Both the length and the width were measured and the halfway point was marked on the paper and lines were drawn at these halfway marks (see Figure 3). The participant then placed their foot back on the paper and their foot was marked at the halfway points. The marks on the foot were then aligned with a grid that intersected at the middle of the force plate (Bertec Co, Columbus, OH), (see Figure 4). Once the foot was aligned properly on the force plate, the participant was instructed to stand as still as possible on their dominant leg for 10 seconds with arms akimbo while looking straight ahead at a target on the wall 8 m away. If the non-dominant leg touched the ground during the 10 second trial, the trial was considered invalid and disregarded. A total of six trials were allowed to complete three valid trials with 30 seconds rest between each trial. Trials with the individuals eyes closed were then measured. All of the static balance measures were collected at 50 Hz. Raw data was integrated with the MotionMonitor software system (Innovative Sports Training Inc, Chicago, IL) and filtered with a fourth order zero lag low pass Butterworth filter with a cut off frequency of 5 Hz. COP was calculated within MotionMonitor prior to export.

To calculate time to boundary, the distance between the COP in the medial/lateral (ML) direction to the medial and lateral borders of the foot was calculated. If the COP was moving medially, the distance between the COP and the medial border of the foot was calculated and then divided by the instantaneous velocity ML COP. This value represents how long it would take the ML COP to reach the medial border of the foot if it were to continue moving in the same direction without a change in velocity. If the COP is moving laterally, the distance between the COP and the lateral border of the foot was calculated then divided by the ML COP instantaneous velocity. The same procedures were repeated in the anterior/posterior (AP) direction[20]. The absolute minimum, mean of the minima and standard deviation of the minima of the time to boundary for each trial was calculated for eyes open and eyes closed using a custom built LabVIEW program (National Instruments, Austin, TX).

Dynamic Balance

To assess TTS, participants maximum vertical jump height was measured using a Vertec vertical jump measuring device (Sports Imports, Columbus, OH). They were instructed to stand with their feet shoulder width apart, jump as high as possible using both legs and at maximum height of their jump hit the vanes on the Vertec device. Participants were allowed to use a countermovement, but could not take a running start or a step to assist in the jump height. Each participant completed three trials with 30 seconds rest between each trial. The highest vertical jump of the three trials was considered the maximum vertical jump. Once maximum vertical jump was measured, the lowest vane on the Vertec was adjusted to 50% of the participant’s maximum jump height. The participant then stood 70 cm from the center of the force plate and was instructed to jump off both feet, touch the lowest plastic vane, land on their dominant leg, and balance for 20 seconds. Trials were excluded if the subject could not maintain balance for 20 seconds, they did not land on the force plate, or there was a hop after landing. Participants completed three valid trials with 30 seconds rest between trials. Participants were allowed a total of six trials to complete three valid trials. Three dimensional ground reaction forces were sampled at 200 Hz.

Raw GRF data was filtered with a fourth order low pass zero lag Butterworth filter with a cut off frequency of 5 Hz. The first three seconds after initial ground contact (defined as > 10 N of vertical GRF) were analyzed. Unit-less stability index scores were calculated for AP (APSI), ML (MLSI) and vertical (VSI) directions (see Figure 5)[43]. The stability indices (SI) imply how stable the GRF is in the three seconds post ground contact, with a lower SI associated with better balance. A composite dynamic posture score (DPSI) of the APSI, MLSI and VSI was calculated as well. Forces were normalized to body mass, so fluctuations around the AP and ML axes were about 0 and fluctuations around the vertical axis were 1.

Balance Screening

At the pre-test session, participants were also screened to determine their baseline level within the traditional training program. Participants started at Level 1 and maintain balance for 30 seconds with their eyes open. If the participant was successful, they moved to the next level until they were unable to maintain balance for the prescribed length of time. Once they lost balance, they repeated the screening process from Level 1 with their eyes closed. See Figure 6 for specific levels. Participants in the traditional balance group began the balance program at the level they lost balance. The screening was only performed at the pre-test.

Agility

Participant's agility was tested via the Arrowhead Agility Test (AAT), a measure of an individual's ability to maintain balance while accelerating, decelerating and changing direction. All of the agility testing was performed in a gymnasium. Individuals were instructed to run and cut around three cones in an arrowhead shape (see Figure 7). The test was then repeated in the opposite direction.

Participants were given a practice trial in each direction. After the practice trials, they completed a total of four trials, two in each direction with 60 seconds rest between each trial. If a participant made contact with the cone or stepped over a cone rather than around, the trial was disguarded and was repeated. Sparq timing gates (Nike Inc, Beaverton, OR) were used to time the participants as they completed the Arrowhead Agility Test.

Balance Programs

Participants were divided into two groups: the traditional balance program and the differential training balance program. Participants were randomly assigned to the different balance training programs in the following manner. In total, there were four individuals, two male and two females, with CAI. Individuals with CAI were first separated from the individuals without CAI. Then males and females in both the CAI and healthy groups were divided randomly into the two training programs. This was done to ensure that there were equal numbers of both individuals with CAI and individuals without CAI in each training group. There were a total of 17 participants in the differential learning training group and 16 participants in the traditional training group.

Both programs were completed three times a week for four weeks as part of the team warm up before team activities during the non-traditional spring season. Only the dominant leg was trained over the course of the four weeks. Participants wore sneakers during each of the training sessions. Each session lasted no longer than 10 minutes.

Traditional Balance Training Program

The traditional balance program has been previously used to improve balance in healthy individuals and was based off the premise of performing the balance task in an error-free manner before progressing to a more challenging balance task[29]. Specifically, there were six different levels that progressed from balancing on a hard surface to balancing on a foam pad (see Figure 6). Each of the six levels had two visual conditions, eyes opened and eyes closed. The goal for levels 1-4 was to maintain balance for 30 seconds, followed by 30 seconds of rest. The goals for levels 5 and 6 were 60 seconds and 90 seconds respectively. The task for each trial was to maintain balance on the dominant leg for the prescribed set of time without an error. Errors were defined as: touching down of the non-stance leg, contact of non-stance leg to the testing leg, foot displacement of the stance leg, excessive lateral trunk motion (>30 degrees), removal of either hand from the hip, or excessive hip extension or abduction (>20 degrees) of the non-stance leg. In order to progress to the next level, the participant had to complete four error free trials at the specific level. If the person successfully completed level 6, they would have continued practicing at that level until the conclusion of four week balance training. However, no participants reached level 6 by the completion of the study (see Table 10).

Differential Training Balance Program

Unlike the traditional training program, the individuals in the differential training program performed a variety of other movements while balancing on the dominant leg. For each of the variations, the individuals were asked to perform the task with different velocities, accelerations, rhythms and possibly with different equipment. The varied movements were for each of the different body segments (head, arms, trunk, hips, stance leg, non-stance leg) and, at least one segment was varied during each of the exercises (see Figure 8). If a segment was not included in the task description, participants were allowed to hold that segment at any position that was comfortable for them. None of the exercises were repeated over the course of the training. Additionally, no feedback was provided regarding the quality of movement. A total of eight different balance exercises were performed at each session with the balance exercises lasting for 30 seconds and followed by rest for 30 seconds.

Statistical Analysis

A total of eighteen 2 (group) x 3 (time) mixed-model repeated measures ANOVAs were used to assess differences in static and dynamic balance and agility. Twelve mixed-model repeated measures ANOVAs for the TTB measurements were performed. The dependent variables for TTB were absolute minimum, mean of minima, and standard deviation of the minima. They were calculated for the eyes open and eyes closed conditions for both the medial/lateral (ML) and anterior/posterior (AP) directions. Four mixed-model repeated measures ANOVAs were done for dynamic balance. The dependent variables were stability indices in the AP, ML and vertical directions as well as the composite stability index. Finally, two mixed-model repeated measure ANOVAs were done for the Arrowhead Agility test, one to the right and one to the left (see Figure 9 for a list of all the dependent variables tested). Alpha level was set a priori 0.05. SPSS 19 (SPSS Inc, Chicago, IL) was used for all statistical analyses.

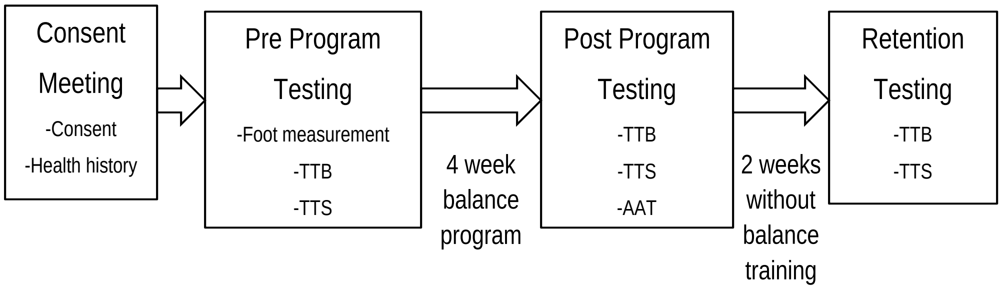

Figure 1. Timeline of Study

Figure 2. Foot Placement in Custom Built L-shaped Panel

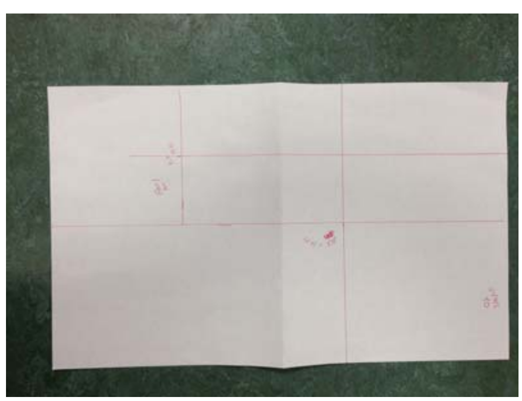

Figure 3. Foot Modeled as Rectangle with Bisecting Lines

Figure 4. Foot Alignment on Force Plate

APSI = $\sqrt{[\sum(0-x)^2 \ /\#data\ points]}$

MLSI = $\sqrt{[\sum(0-y)^2 \ /\#data\ points]}$

VSI = $\sqrt{[\sum(1-z)^2 \ /\#data\ points]}$

DPSI = $\sqrt{[[\sum(0-y)^2 + \sum(0-x)^2 + \sum(1-z)^2 \ ]/\#data\ points]]}$

Figure 5. Equations Used to Calculate Stability Indices[44]

Figure 6. Balance Screening/Traditional Balance Program Levels

Eyes Open	Eyes Closed
1o: arms out on hard floor	1c: arms out on hard floor
2o: hands on hips on hard floor	2c: hands on hips on hard floor
3o: arms out on foam pad	3c: arms out on foam pad
4o: hands on hips on foam pad	4c: hands on hips on foam pad
5o: hands on hips on foam pad (60 seconds)	5c: hands on hips on foam pad (60 seconds)
6o: hands on hips on foam pad (90 seconds)	6c: hands on hips on foam pad (90 seconds)

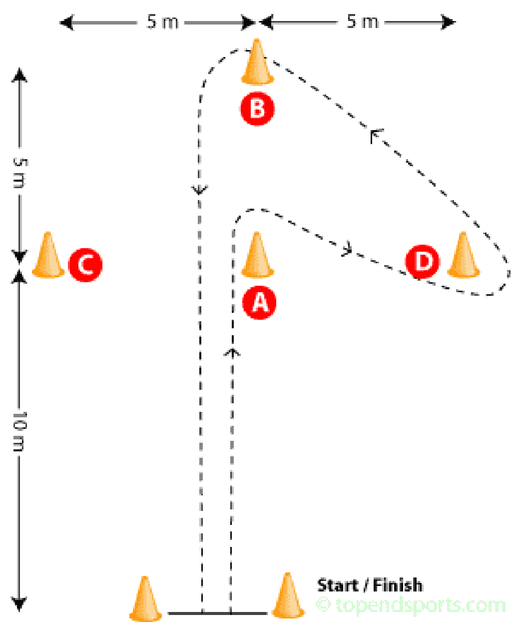

Figure 7. Arrowhead Agility Test. Participants were instructed to begin at the start line, run as fast as possible to the middle cone [A], then around the side cone [D], then around the far cone [B], and finally to the start/finish line. The participant's rested 60 seconds after the trial. The participant's then were instructed to repeat the test in the opposite direction (i.e., they ran to the opposite side cone [C] instead of cone [D]).

Figure 8. Differential Training Segmental Breakdown

HEAD	ARMS	TRUNK	HIPS	STANCE LEG	NON STANCE LEG
Lateral bend	Overhead	Alphabet hips	Kicking motion: shoot	Dorsiflexed	Valgus
Flexion	Behind head	Trunk circles clockwise	Kicking motion: volley	Planter flexed	Quad stretch
Extension	Sprinkler	Trunk circles counterclockwise	Kicking motion: pass	Inverted	Butt kickers
Rotation	Arm circles forward	Oblique crunches	Internally rotated stance leg	Everted	High knees
	Arm circles backward	Lateral bends	Externally rotated stance leg	Calf raises	
	Scaption	Romanian dead lifts	Tree pose	Toe curls	
	Upright row	Flexion	Medial circumduction of non stance leg		
	Jumping jack arms	Extension	Lateral circumduction of non stance leg		
	Namaste	Rotation	High kicks		
	Finger to nose	Squats	Lateral kicks		
	Windmill		Leg swings anterior/posterior		
	Bicep curl with dumbbells		Leg swings medial/lateral		
	Tricep extension with dumbbells		Leg circles		
	Abduction				
	Criss cross				
	Ball toss				

Figure 9. Dependent Variables

STATIC BALANCE (TTB)		DYNAMIC BALANCE (TTB)	AGILITY
Eyes Open	Eyes Closed	APSI	Right
ML absolute minimum	ML absolute minimum	MLSI	Left
ML mean of minima	ML mean of minima	VSI	
ML standard deviation of minima	ML standard deviation of minima	DPSI	
AP absolute minimum	AP absolute minimum		
AP mean of minima	AP mean of minima		
AP standard deviation of minima	AP standard deviation of minima		

CHAPTER 4 - RESULTS

Over the course of the study, four participants were injured during team activity and one did not show up for final testing, leaving twenty-eight participants who completed the entire study. Of the four CAI individuals, only two completed the study (both males with CAI did not complete the study due to injury). None of the participants, including those that dropped out due to injury, sustained an ankle injury during the course of the study.

Static Balance

Prior to analysis, data were first checked to ensure assumptions of the statistical test performed were met and to screen for outliers. There were two individuals who had trials of the ML mean of the minima for the EO condition that were over 3 standard deviations. Those individual trials were excluded from analysis. Means and standard deviations for each of the dependent variables are shown in Tables 1 and 2.

For the ML direction, there were no significant interactions between group and time for any of the TTB dependent variables (all test statistics can be seen in Tables 3 and 4). However, there were several main effects for time. In the ML eyes open condition, pairwise comparisons showed significant changes from post- to retention test for mean of minima ($p = 0.003$) and standard deviation of minima ($p = 0.011$). In the eyes closed condition, there was also a significant time effect. Pairwise comparisons showed differences from pre- to post-test for mean of minima ($p < 0.001$) and standard deviation of minima ($p < 0.001$).

In the anterior/posterior (AP), there was no interaction between group and time for any of the dependent variables. In the eyes open condition, there was a significant time main effect for the absolute minimum and a pairwise comparison showed that it was from pre- to post-test ($p = 0.003$). In the eyes closed condition, there was a significant time main effect for absolute minimum and a pairwise comparison showed differences from pre- to post-test ($p = 0.023$). There was also a main effect for group for the mean of the minima; the traditional group was higher ($p = 0.032$).

Dynamic Balance

Data were first checked to ensure assumptions of the statistical test performed were met and to screen for outliers prior to any testing. There were no outliers, however, Mauchly's test of sphericity showed that the data violated the assumption of sphericity for both VSI ($p = 0.001$) and DPSI ($p = 0.001$), so the Greenhouse-Geisser correction was used for both VSI ($p = 0.684$) and DPSI ($p = 0.695$). Means and standard deviations are shown in Table 5. There was no significant interaction between group and time for any of the dependent variables (all test statistics can be seen in Table 6). There was a significant time main effect. Pairwise comparisons revealed significant differences for all of the variables in the pre- and post-test, pre- and retention and post- and retention test (see Table 6 for the p values).

Arrowhead Agility Test

Assumptions of the statistical test performed were checked as well as screening for outliers previous to any statistical analysis being performed. The assumptions were met and there were no outliers. There was a recording error in 10 participants' post-test agility runs and, therefore they were removed from all data analyses. Means and standard deviations are shown in Table 8. There were no significant interactions between group and time (all test statistics can be seen in Table 9). There were also no main effects across the data.

Table 1. Medial/Lateral Static Balance Means and Standard Deviations

DIRECTION	VISUAL CONDITION	DV (sec)	GROUP	PRE	POST	RET
MEDIAL LATERAL	EYES OPEN	*ABS MIN*	DIFF	0.038 ± 0.007	0.038 ± 0.006	0.038 ± 0.007
			TRAD	0.037 ± 0.008	0.037 ± 0.007	0.040 ± 0.005
		MEAN MIN	DIFF	3.490 ± 1.232	3.590 ± 1.123	3.959 ± 1.141
			TRAD	3.108 ± 0.755	3.099 ± 1.040	3.622 ± 0.965
		SD	DIFF	6.386 ± 2.897	5.654 ± 2.587	6.777 ± 2.858
			TRAD	5.634 ± 2.647	4.651 ± 1.715	6.272 ± 2.050
	EYES CLOSED	*ABS MIN*	DIFF	0.032 ± 0.007	0.036 ± 0.010	0.036 ± 0.010
			TRAD	0.037 ± 0.007	0.036 ± 0.006	0.041 ± 0.007
		MEAN MIN	DIFF	1.477 ± 0.498	1.900 ± 0.580	1.593 ± 0.301
			TRAD	1.651 ± 0.353	1.993 ± 0.545	1.879 ± 0.561
		SD	DIFF	2.598 ± 1.435	3.925 ± 2.150	2.787 ± 0.796
			TRAD	2.567 ± 0.709	3.741 ± 1.507	3.337 ± 1.631

Table 2. Anterior/Posterior Static Balance Means and Standard Deviations

DIRECTION	VISUAL CONDITION	DV (sec)	GROUP	PRE	POST	RET
ANTERIOR POSTERIOR	EYES OPEN	*ABS MIN*	DIFF	0.050 ± 0.007	0.053 ± 0.006	0.050 ± 0.005
			TRAD	0.051 ± 0.007	0.053 ± 0.007	0.054 ± 0.006
		MEAN MIN	DIFF	9.682 ± 2.517	9.370 ± 1.807	10.367 ± 2.997
			TRAD	9.290 ± 2.827	9.621 ± 2.578	9.720 ± 3.176
		SD	DIFF	14.224 ± 5.473	13.515 ± 4.257	16.303 ± 8.55
			TRAD	12.832 ± 4.561	13.524 ± 4.399	14.764 ± 7.192
	EYES CLOSED	*ABS MIN*	DIFF	0.047 ± 0.009	0.050 ± 0.009	0.047 ± 0.006
			TRAD	0.050 ± 0.008	0.054 ± 0.007	0.052 ± 0.006
		MEAN MIN	DIFF	3.942 ± 1.126	3.997 ± 1.261	3.853 ± 0.763
			TRAD	4.395 ± 1.218	4.590 ± 1.026	4.749 ± 1.559
		SD	DIFF	5.847 ± 2.499	5.817 ± 2.762	5.374 ± 1.863
			TRAD	6.809 ± 2.891	6.090 ± 1.667	6.736 ± 2.822

Table 3. TTBML Eyes Open Statistical Analysis Results.

		ABSOLUTE MINIMUM	MEAN OF MINIUM	STANDARD DEVIATION OF MINIMUM
EYES OPEN	INTERACTION	p = 0.372	p = 0.863	p = 0.816
	TIME MAIN EFFECT	p = 0.299	p = 0.049*	p = 0.044*
	Pre to Post	p = 0.333	p = 0.975	p = 0.052
	Post to Retention	p = 0.108	p = 0.029*	p = 0.011*
	Pre to Retention	p = 0.666	p = 0.051	p = 0.671
	GROUP MAIN EFFECT	p = 0.800	p = 0.876	p = 0.450
EYES CLOSED	INTERACTION	p = 0.402	p = 0.556	p = 0.316
	TIME MAIN EFFECT	p = 0.085	p = 0.002*	p = 0.005*
	Pre to Post	p = 0.429	p < 0.001*	p < 0.001*
	Post to Retention	p = 0.137	p = 0.134	p = 0.151
	Pre to Retention	p = 0.067	p = 0.111	p = 0.076
	GROUP MAIN EFFECT	p = 0.266	p = 0.149	p = 0.816

* indicates significance

Table 4. TTBAP Statistical Analysis Results.

		ABSOLUTE MINIMUM	MEAN OF MINIUM	STANDARD DEVIATION OF MINIMUM
EYES OPEN	INTERACTION	p = 0.216	p = 0.657	p = 0.837
	TIME MAIN EFFECT	p = 0.006*	p = 0.675	p = 0.383
	Pre to Post	p = 0.003*	p = 0.941	p = 0.993
	Post to Retention	p = 0.440	p = 0.467	p = 0.248
	Pre to Retention	p = 0.026*	p = 0.498	p = 0.299
	GROUP MAIN EFFECT	p = 0.430	p = 0.880	p = 0.580
EYES CLOSED	INTERACTION	p = 0.746	p = 0.674	p = 0.437
	TIME MAIN EFFECT	p = 0.037*	p = 0.646	p = 0.925
	Pre to Post	p = 0.023*	p = 0.432	p = 0.960
	Post to Retention	p = 0.070	p = 0.959	p = 0.735
	Pre to Retention	p = 0.283	p = 0.398	p = 0.748
	GROUP MAIN EFFECT	p = 0.075	p = 0.032*	p = 0.311

* indicates significance

Table 5. Dynamic Balance Means and Standard Deviations

	GROUP	PRE	POST	RET
MLSI	DIFF	0.038 ± 0.007	0.035 ± 0.007	0.015 ± 0.006
	TRAD	0.036 ± 0.009	0.032 ± 0.008	0.014 ± 0.004
APSI	DIFF	0.106 ± 0.010	0.104 ± 0.008	0.045 ± 0.018
	TRAD	0.103 ± 0.011	0.102 ± 0.009	0.041 ± 0.003
VSI	DIFF	0.414 ± 0.059	0.373 ± 0.055	0.569 ± 0.053
	TRAD	0.370 ± 0.051	0.353 ± 0.042	0.583 ± 0.003
DPSI	DIFF	0.429 ± 0.058	0.389 ± 0.054	0.572 ± 0.049
	TRAD	0.386 ± 0.051	0.369 ± 0.040	0.585 ± 0.003

The SI values are unitless.

Table 6. TTS Statistical Analysis Results.

	MLSI	APSI	VSI	DPSI
INTERACTION	$p = 0.687$	$p = 0.808$	$p = 0.058$	$p = 0.059$
TIME MAIN EFFECT	$p < 0.001$*	$p < 0.001$*	$p < 0.001$*	$p < 0.001$*
Pre to Post	$p = 0.046$*	$p = 0.161$	$p < 0.001$*	$p < 0.001$*
Post to Retention	$p = 0.001$*	$p <0.001$*	$p < 0.001$*	$p < 0.001$*
Pre to Retention	$p = 0.002$*	$p < 0.001$*	$p < 0.001$*	$p < 0.001$*
GROUP MAIN EFFECT	$p = 0.149$	$p = 0.610$	$p = 0.193$	$p = 0.190$

* indicates significance

Table 7. Vertical Jump Means

MAX HEIGHT (CM)	PRE	POST	RET
DIFF	53.34 ± 6.60	53.72 ± 7.87	53.98 ± 9.09
TRAD	56.21 ± 9.25	58.65 ± 10.95	57.66 ± 10.34

No significant changes between group or across time.

Table 8. Arrowhead Agility Test Means and Standard Deviations

SIDE	GROUP	PRE	POST	RET
RIGHT	DIFF	8.960 ± 0.568	9.009 ± 0.394	9.094 ± 0.498
	TRAD	9.005 ± 0.511	9.009 ± 0.449	9.019 ± 0.552
LEFT	DIFF	8.904 ± 0.483	9.129 ± 0.400	9.153 ± 0.523
	TRAD	9.002 ± 0.529	9.163 ± 0.562	9.095 ± 0.631

Units are in seconds.

Table 9. Arrowhead Agility Test Statistical Analysis Results

	RIGHT	LEFT
INTERACTION	p = 0.981	p = 0.933
TIME MAIN EFFECT	p = 0.509	p = 0.430
Pre to Post	p = 0.177	p = 0.107
Post to Retention	p = 0.337	p = 0.964
Pre to Retention	p = 0.953	p = 0.371
GROUP MAIN EFFECT	p = 0.935	p = 0.327

Table 10. Traditional Balance Program Starting and Ending Levels

SUBJECT	EO PRE	EO POST	EC PRE	EC POST
01	5	5	3	3
02	3	3	1	1
03	1	4	1	1
08	5	5	1	1
09	3	3	1	1
10	4	5	1	1
11	5	5	1	1
12	5	5	1	2
13	3	5	1	2
16	2	4	1	1
17	4	4	1	1
22	3	3	1	1
29	3	4	1	1

CHAPTER 5 - DISCUSSION

We hypothesized there would be equivocal results between the differential training program and the traditional balance program after the four-week training, but the participants in the differential training group would demonstrate increased retention after two weeks of no training. Although we did find that the differential training had equivocal results to the traditional program, there were no differences in retention on any of the static or dynamic balance measures or agility tests when compared to the traditional program.

Static Balance

Time to boundary consists of three separate measures of the COP: absolute minimum, mean of minima and standard deviation of the minima. Each of these measurements is recorded in both the ML and AP direction with both the eyes open and eyes closed. Absolute minimum and mean of the minima represent how long it takes an individual to make postural corrections. The greater the absolute minimum and mean of the minima, the more time an individual has to correct themselves, and thus, the person is considered to be more stable[20]. Standard deviation of the minima represents the different ways an individual recovered when correcting their postural control. It is thought that the greater standard deviations infer greater solutions since the variability of responses has increased.

Examination of the ML eyes open condition revealed no significant differences from the pre- to post- tests in any of the ML measures. However, both groups improved from the post- to retention tests in the ML direction for the mean of the minima and the standard deviation (See Figure 10). Improving the mean of the minima suggests that the participants improved their balance because it took them more time for their COP to get to the border of the base of support, thus allowing more time to react to the moving COP. The increase in standard deviation implies that participants in both groups theoretically used a greater amount of solutions to maintain their postural control. Having a greater amount of solutions available theoretically allows for individuals to be able to recover their balance more efficiently in new and possible injurious situations. One explanation of both groups improving from the post- to retention tests is that the balance training improved their balance in the ML direction. Another explanation for the improvements by both groups is that there might have been a learning effect from performing the task for the third time. The use of a control group may have provided us more insight into the reason (learning effect or actual improvement of balance) for the improvement. We did not use a control group in this study due to the limited number of participants available and because this was a clinical study so it would not have been appropriate for individuals to sit out of a team warm up. Future studies may want to incorporate a control group in order to provide more information about the difference in results.

During the eyes closed condition, both the differential and traditional training groups improved from the pre- to post-tests in the ML direction for mean of the minima and standard deviation (See Figure 11). No changes were noted from the post- to retention tests. This indicates that after the four-week training program both groups increased their balance by decreasing their sway. Also, they both increased the amount of possible solutions to regain postural control. It is important to note that there was no statistical significance between the pre- and retention tests. This implies that although both groups initially increased their balance, it seems that after the two-week retention, they were on a downward trend and returning toward their pre-test balance. In other words, the increase in balance, as measured by TTB, was not retained.

The only time that there was a difference between groups was during the AP mean of the minima during the eyes closed condition. This is to be expected as the traditional group did half of their training with their eyes closed. But what is noteworthy is that during both the eyes open and closed conditions, improvements in the AP absolute minimum were noted from pre- to post-tests for both groups (See Figures 12 and 13). It might be expected that the traditional group improved their balance with their eyes closed because half of their training was performed with their eyes closed. However, the differential training group did not ever perform any exercises with their eyes closed. One possible explanation is because of all the different exercises performed in the differential training, the differential training group was able to adapt to the constraint of eyes closed even though it was not practiced. Another thought is that absolute minimum might not be the best measurement of static balance, as it only looking at one extreme, which does not encompass static balance as a whole and it gave different results than the mean of the minima. In fact, examination of the PPC of the absolute minimum to both the mean of the minima and the standard deviation of the minima of all three testing periods, it reveals no relationship ($r = -0.032$, $r = 0.042$ for pre tests, see Appendix H for all PPC values).

In addition to absolute minimum and the mean of the minima, standard deviation of the minima was used as another look at TTB. Standard deviation of the minima is most relatable to differential training because the main concept of differential training is that performing tasks with error/perturbation allows for an individual to adapt to changing environmental, task or body constraints during movement. Since the differential training group balanced with errors and had a broader base of unbalanced experiences, the thought was that they would have used more options to regain their balance. By having used more options in the training, we hypothesized that the differential training group would continue to use these options in the testing as well. Under this thought process, it would be expected that the differential training participants would have an increased standard deviation in both the AP and ML directions when compared to the traditional training group[20]. There was no group difference in either the AP or ML standard deviations (for both visual conditions). Future research should be done to consider the meaning of variability of COP measures.

In addition to the statistical analyses, we also decided to qualitatively examine individual TTB response to the training programs. Interestingly, it appears there were different responses to both types of training. Several individuals had greater MLTTB measures but had lesser APTTB measures and vice versa (See Figures 14-17). This could suggest that individuals learn to stabilize more in one direction and rely more on either the AP or ML direction rather than combining both. For example, participant 10 shows a dramatic increase in MLTTB (Figure 14) but in the APTTB they show a very small increase (Figure 16). The opposite can be said for participant 2. They had a decrease in the MLTTB (Figure 14) but a large increase in the APTTB (Figure 16). It seems that the different strategies could be different responses to the training program, since the individuals seem to differ most in the post-test data. Further research should be done to investigate different balancing strategies, as it could indicate different neuromuscular responses or mechanisms. Perhaps certain individuals are more prone to increasing balance in one direction over another or individuals may respond differently to balance training programs. By investigating individual balance strategies, it may provide insight into why certain individuals tend to have reoccurring ankle injury while others do not. Those who suffer from CAI may have a different type of response to balance training then those who don't have CAI. Due to our small sample size, we may not have been able to see the differences between the responders and non-responders. With increased power, future studies may be better to ascertain if this hypothesis is correct.

Dynamic Stabilization

Time to stabilization (TTS) measures how quickly an individual stabilizes their ground reaction forces after landing from a jump. When using TTS as a measure of balance, four different stability indices are reported. They represent three different directions of ground reaction force: medial/lateral (MLSI), anterior/posterior (APSI) and vertical (VSI). The fourth stability index is the dynamic postural stability index (DPSI), which is a composite of MLSI, APSI and VSI and gives insight into how an individual stabilizes after the perturbation in all directions.

MLSI for both training groups showed a significant decrease from the pre- to post-test, the post- to retention test and the pre- to retention test (Figure 18). APSI for both training groups showed a significant decrease from the post- to retention test and the pre- to retention test (Figure 19). The decrease in TTS means that it took less time to stabilize the GRF in the ML and AP directions, implying that dynamic balance had improved. The VSI showed a significant decrease from pre- to post-tests, but an increase from post- to retention testing for both training groups (Figure 20). In other words, balance was improved immediately after the training programs but then got significantly worse, even worse than the pre-test. While this is not fully understood, it could be due to the fact that the individuals changed how they landed from the jump over time due to a learning effect over the course of the study. For the first two testing sessions, the participants may have landed in a way to decrease their GRF as they were unsure of how difficult the jump was since it was either their first or second time performing the jump and there was a four-time difference between testing periods (as compared to only two-weeks between the post-test and retention test). By having a softer landing, it would allow them to regain stability faster since they would have more room to catch themselves. During the retention tests, the participants may have landed stiffer, as they were accustomed to the jump and landing task and knew what it would take to stabilize after the jump. A stiffer landing would lead to a higher vertical ground reaction force, and thus a higher VSI[7]. Had a control group been used in this study, we would have been able to have a better idea whether a learning effect did occur or if something else was influencing the VSI data.

One issue with TTS is that the dynamic posture stability index (DPSI) may be unduly influence by the VSI. DPSI is calculated by taking into account all three (APSI, MLSI and VSI) stability indices by adding them all together and taking the square root. The DPSI data, it is positively correlated to the VSI data but negatively with both the APSI and the MLSI (APSI:DPSI $r = -0.974$ MLSI:DPSI $r = -0.664$. For complete PPC values, see Appendix H) (Figure 21). The high correlation between the VSI and DPSI ($r = 1.000$) may be due to the fact that the VSI numbers are higher than the MLSI and APSI. It seems that the AP and ML directions would be more significantly related to the overall postural control because when greater sway occurs in those directions, it causes the COP to go outside the base of support leading to a fall or stumble. So using DPSI as a global measure of control to screen for injury risk or return to play assessment is not ideal as it does weigh the APSI and MLSI as strongly as the VSI. It is important to be able to fully understand how each of the directions (vertical, AP and ML) affect the global sense of postural control and make sure that a measure takes each direction into account. Although research has shown that DPSI is just as accurate as other TTS measurements that only incorporate AP and ML ground reaction forces[44], our results suggest that DPSI is relying heavily on the VSI. A previous study has shown similar results to ours[6].

Arrowhead Agility Test

The Arrowhead Agility Test (AAT) was selected as a more functional measure of balance, as it involves maintaining balance while changing direction multiple times. Specifically, the test was used to provide insight into how an individual adapts to changing environment and task constraints. The thought was that it would provide constraints that were more similar to those seen during functional activities. A decrease in time to complete the test implies that an individual is better able to maintain body control while changing directions or a faster sprint time around the cones. There was no significant change in time in either direction (right or left) between the groups or over time (Figures 22 and 23). It could be that the individuals were consistently training and conditioning which kept them in the same condition across the study. Another possible reason could be that the test was not sensitive enough. There was no specific balance activity involved in the running of the test, so although participants may have improved balance, the AAT may not have been able to pick up on those changes. Although this test was more functional than both the static and dynamic balance tasks, it did have some limitations. Primarily, all agility tests were performed in a gymnasium with a wooden floor as compared to a field. Since the floor was wooden, individuals all wore sneakers. Normally, they would perform agility tasks on the field wearing cleats, which would allow them to make faster changes in direction. The gymnasium was used as it provided a constant surface while a field surface could have possibly changed over the course of the study. However, all participants completed the test on the same surface for all three tests, which kept this measure constant across all participants.

Future Directions

Although we did not find many significant differences between the two different training groups, there are still many questions that need to be answered. First, the length of time engaged in the differential balance training program was much less than other differential training for other skills. Specifically, the participants in this study who trained with differential training only practiced balancing for approximately 48 minutes over the course of the four weeks. When calculated for four to six weeks of training, it is obviously much less training time. However, our goal with the study was to have equal amounts of volume between the two balance training programs. Future research should increase the amount of total time that the training is done, either by increasing the amount of time of each session or the total days that the training is completed.

Another factor that might have affected our results could have been that individuals were allowed to wear their own sneakers during the dynamic balance testing (as well as the Arrowhead Agility Testing).

By not accounting for the different types of shoes, it is possible that individuals stabilized their GRFs differently due to their shoe. Future studies should make sure to provide consistent shoes for their participants in order to eliminate the possibility of shoe influence on GRF. Participants also wore shoes during the balance training programs. Although this differed from the Rothermel study, we had the participants wear their shoes because most of the balancing was done outside on the practice field, where it was muddy or wet.

Finally, since participants in this study were Division I college athletes, it may have been they had little room to improve their balance performance. It could be hypothesized that elite athletes already are better able to balance due to their greater sport skill. For this reason, we only tested their kicking leg versus their plant stability leg. We chose the kicking leg because we thought that the plant stability leg would have better balance, and a possibility of less room for balance improvement, then the kicking leg. Additionally, we don't believe a ceiling effect was a factor because balance improved over the course of the study on both ML/AP TTB and AP/ML TTS. Future research should insure the balance testing and training minimize these factors.

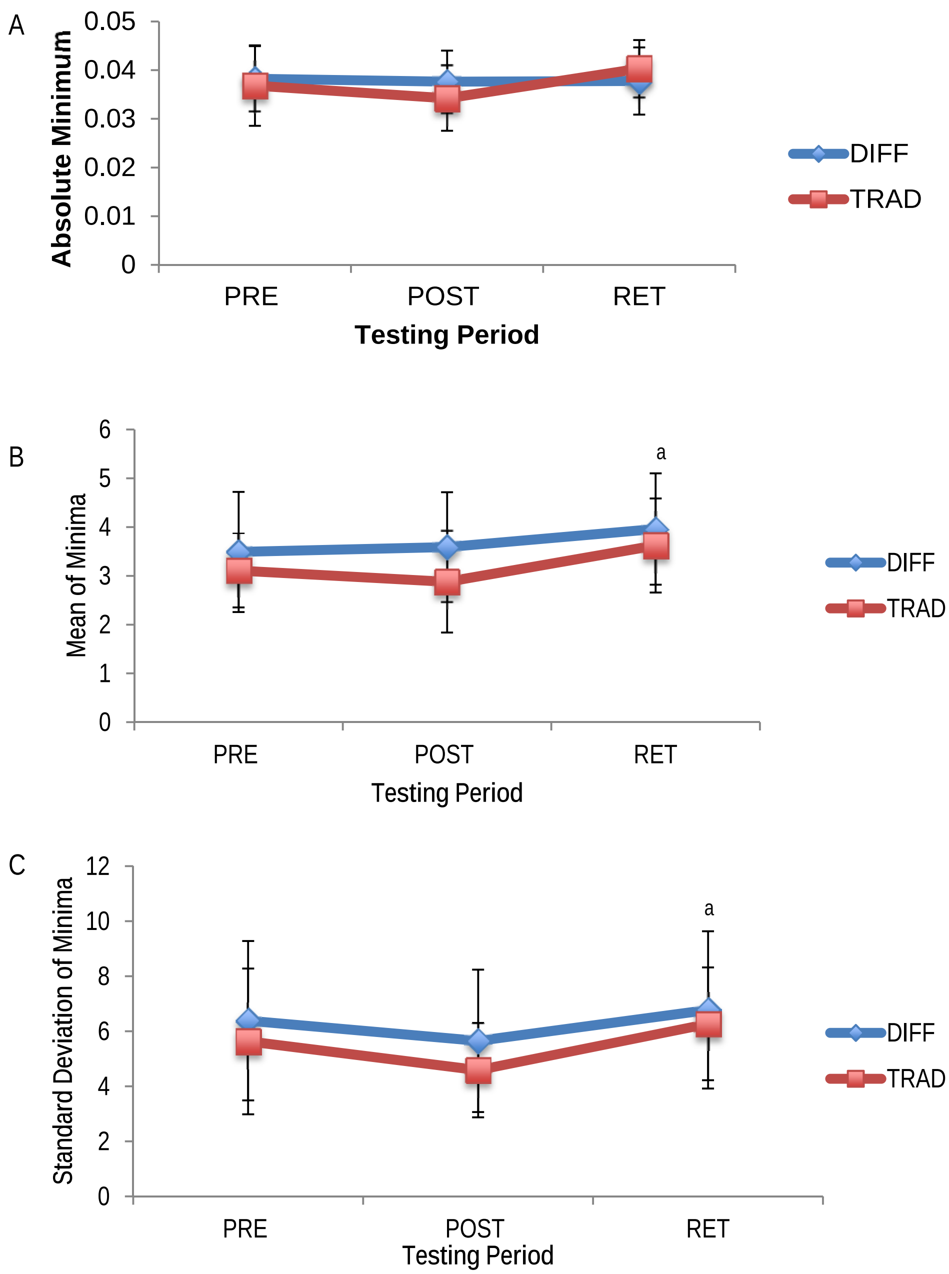

Figure 10. ML TTB measurements during *eyes open* for absolute minimum, A, mean of minima, B, and standard deviation of minima, C. [a] indicates significant difference from post- to retention test.

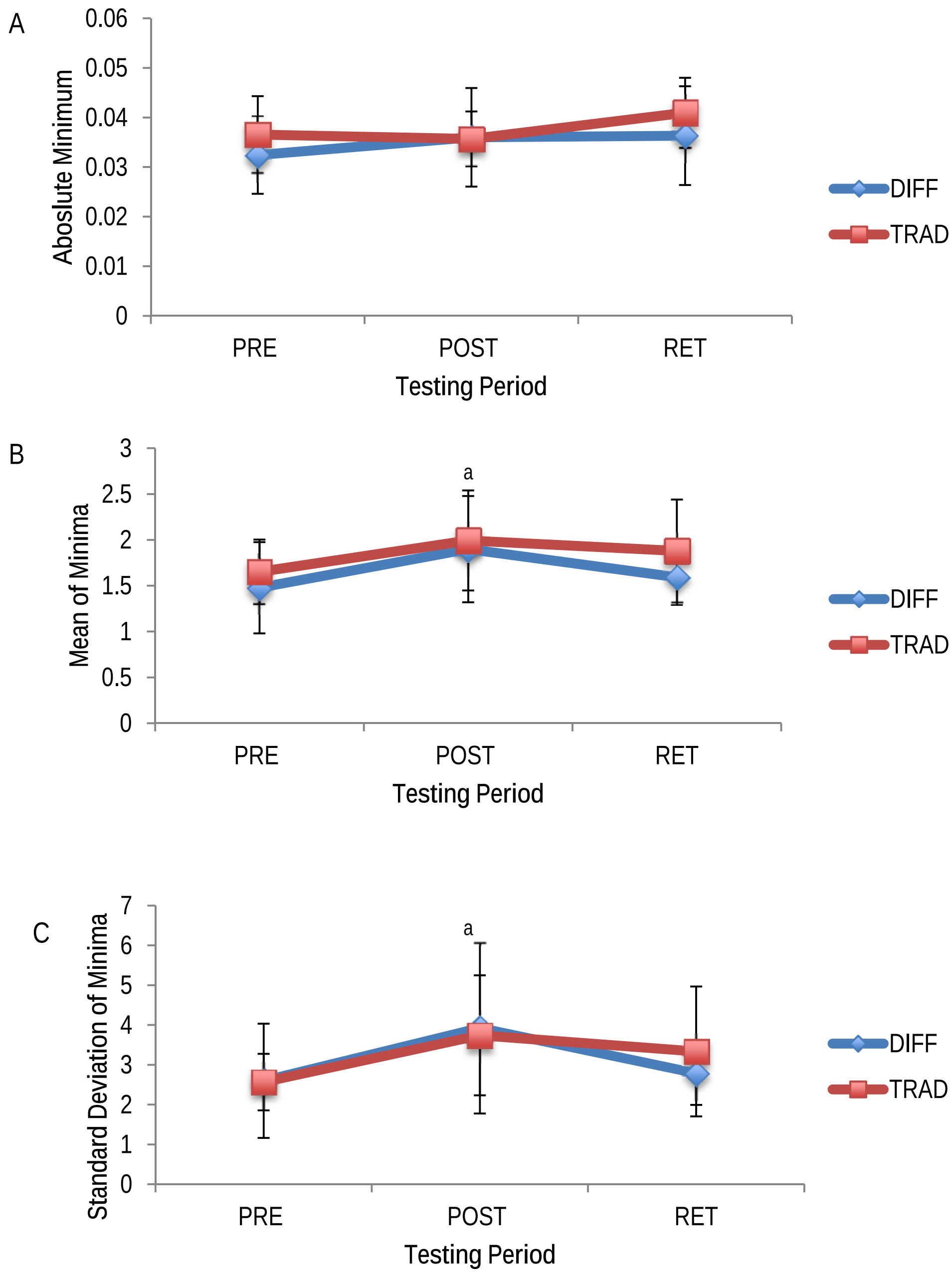

Figure 11. ML TTB measurements during *eyes closed* for absolute minimum, A, mean of minima, B, and standard deviation of minima, C. [a] indicates significant difference from pre- to post-test.

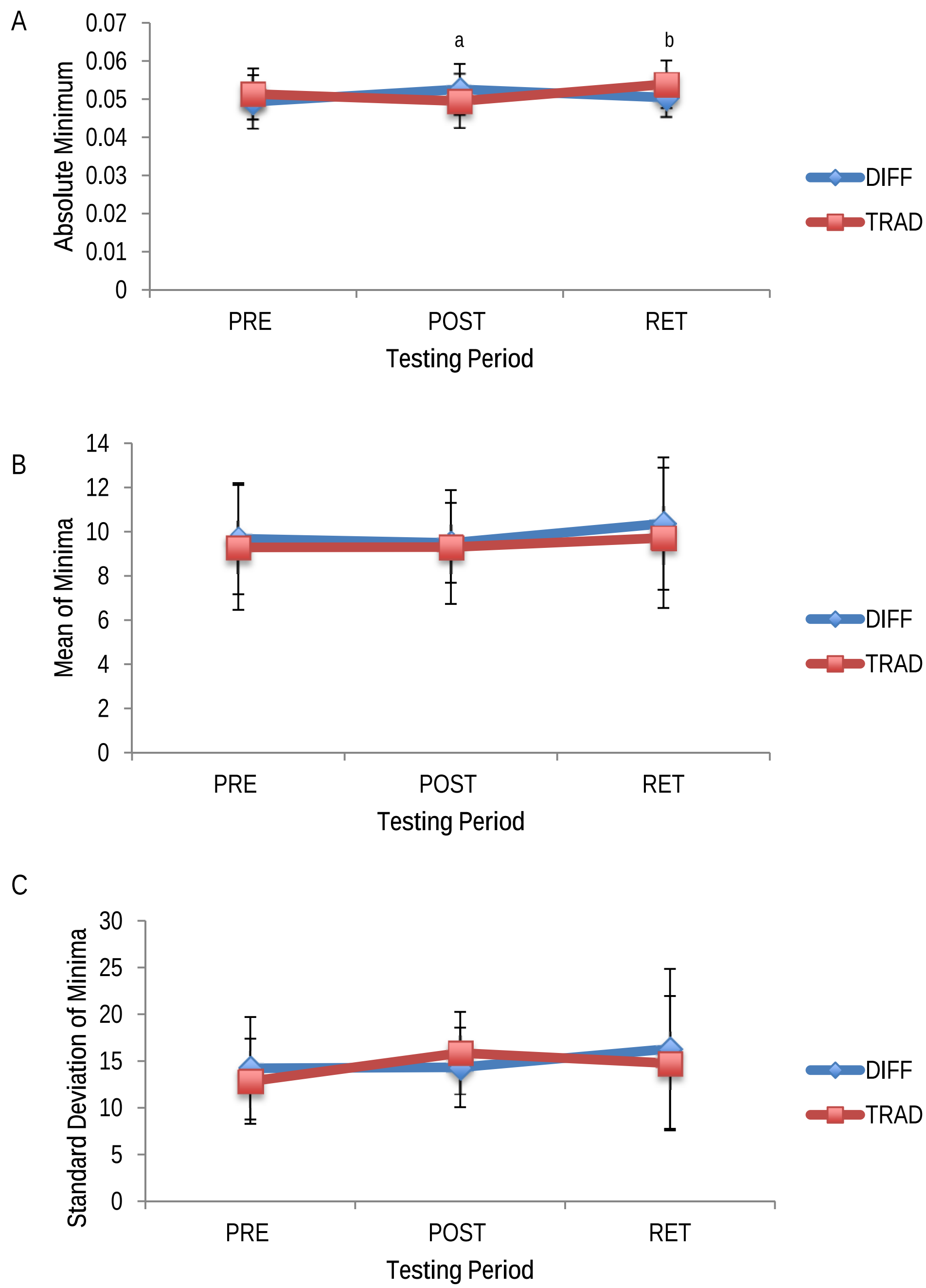

Figure 12. AP TTB measurements during *eyes open* for absolute minimum, A, mean of minima, B, and standard deviation of minima, C. [a] indicates significant difference from pre- to posttest, [b] indicates significant difference from post- to retention test.

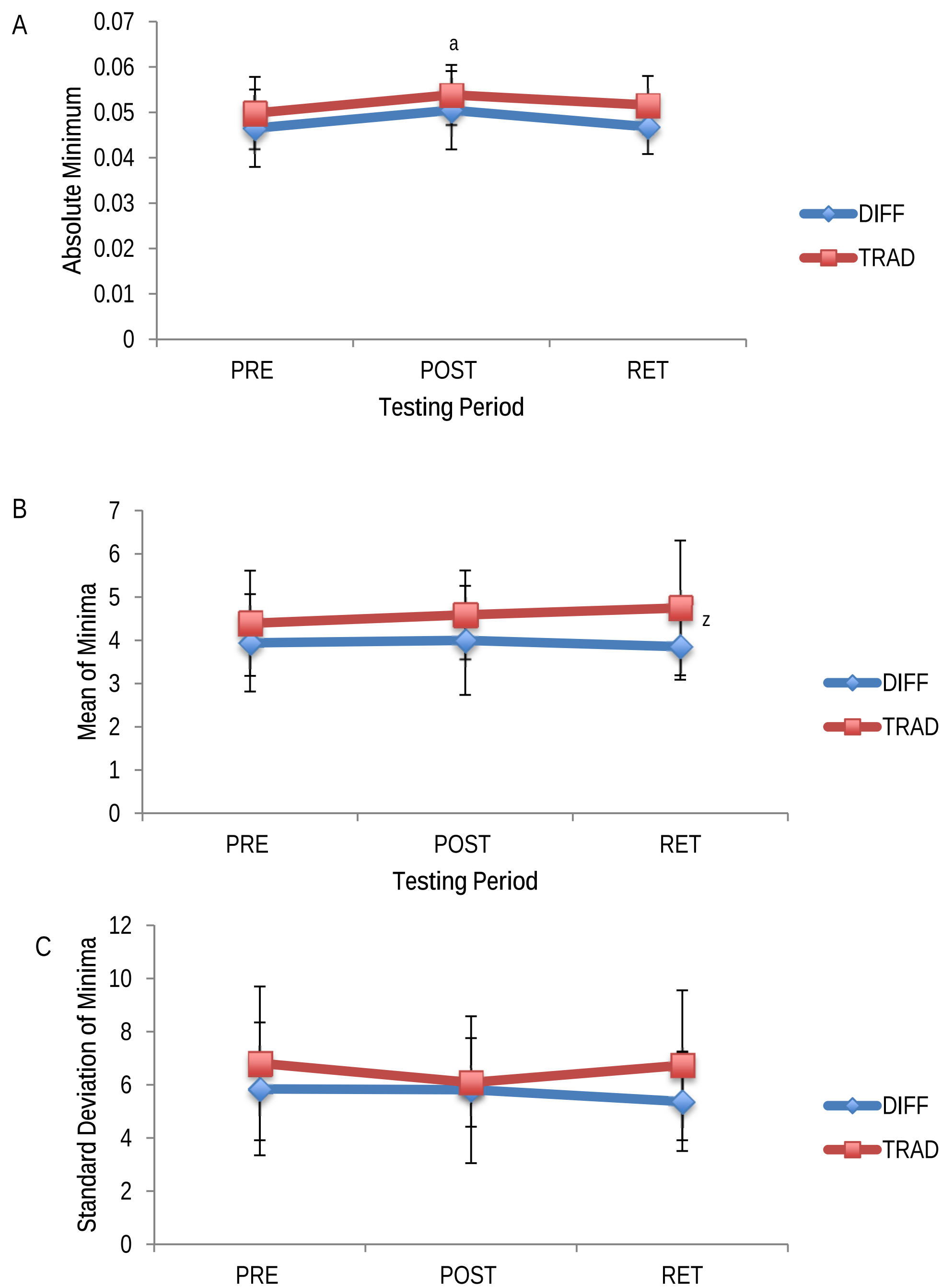

Figure 13. AP TTB measurements during *eyes closed* for absolute minimum, A, mean of minima, B, and standard deviation of minima, C. [a] indicates significant difference from pre- to posttest. [z] indicates a significant difference between groups.

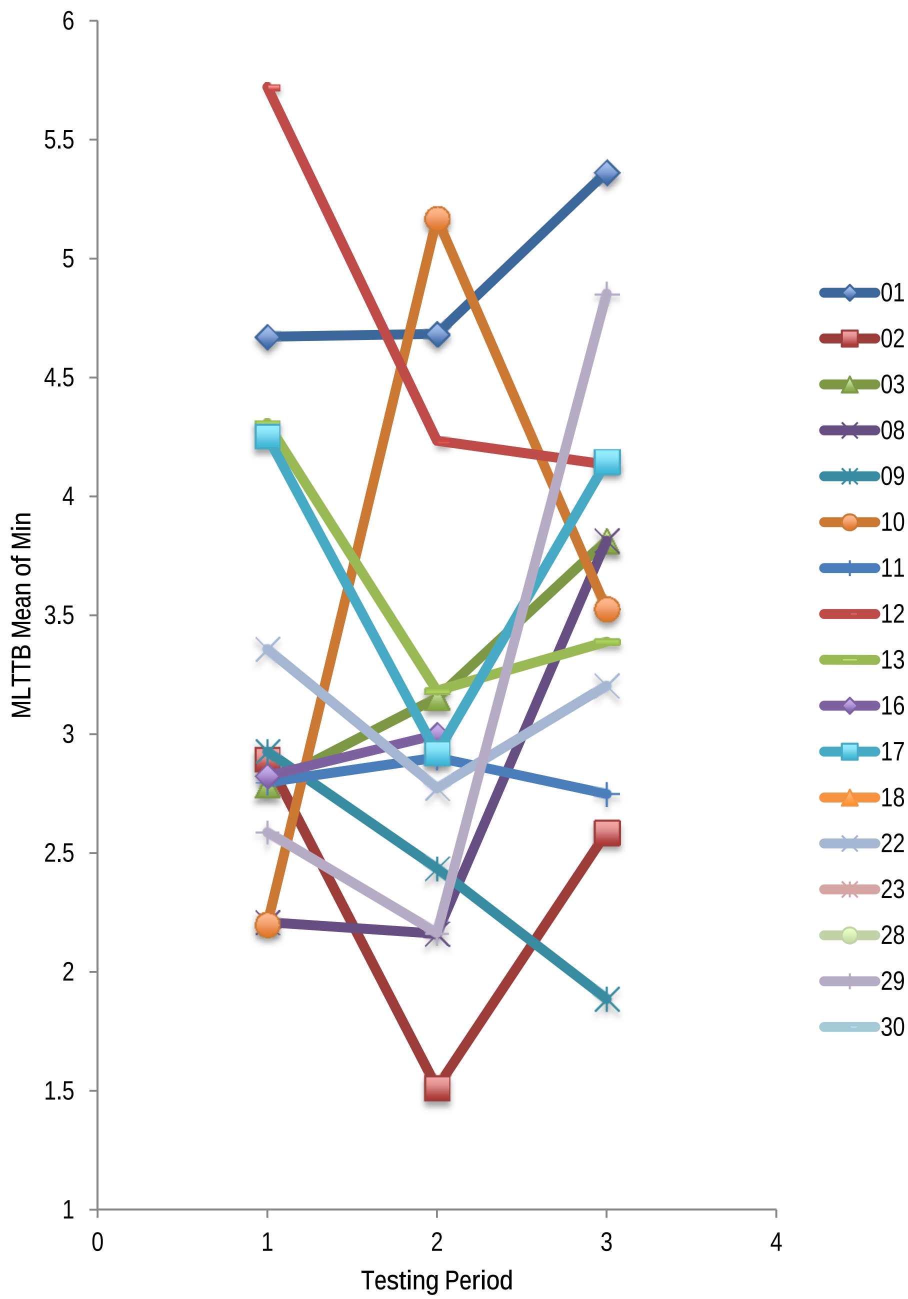

Figure 14. Traditional Group Individual Responses to Training (ML TTB MEAN OF MIN)

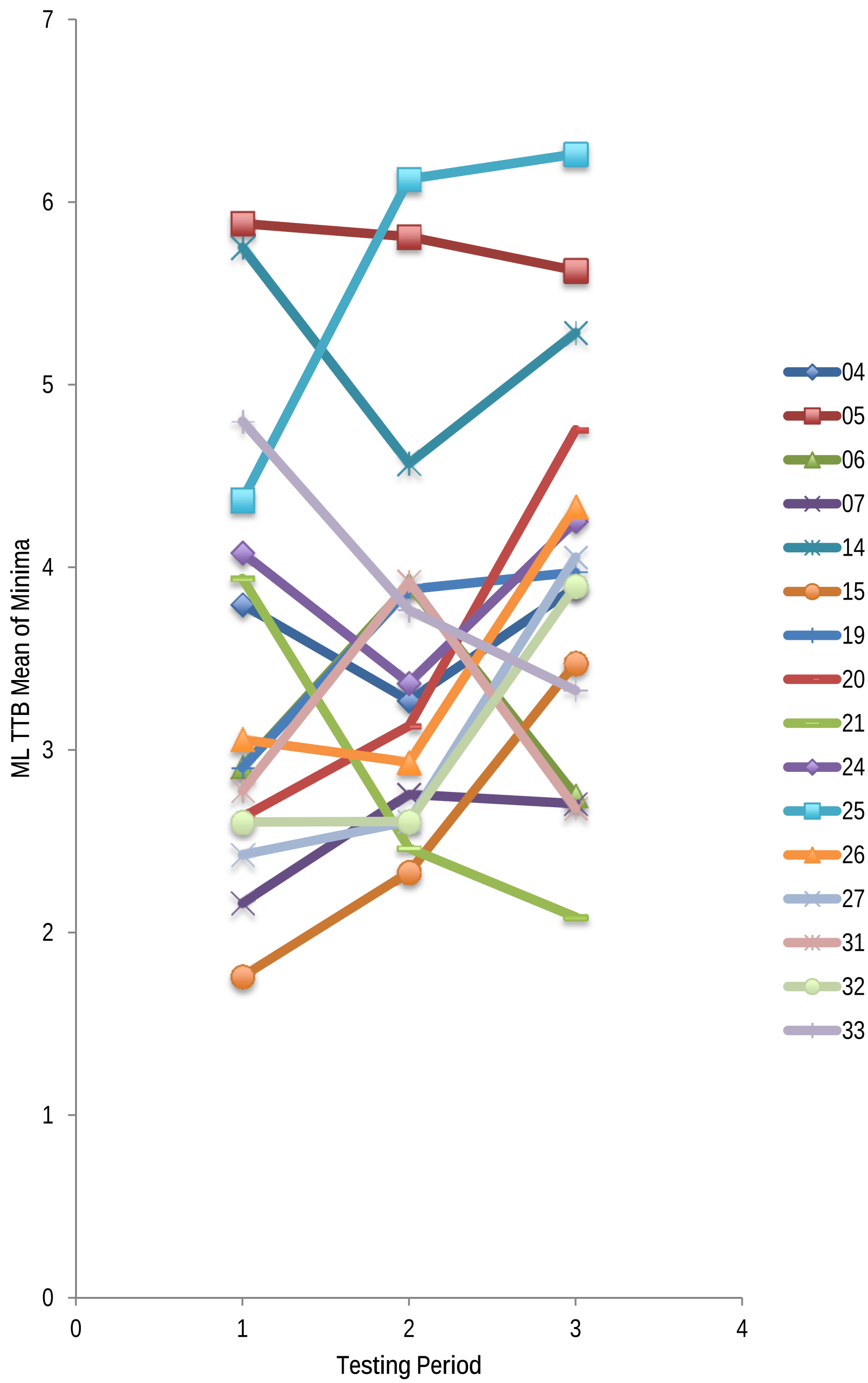

Figure 15. Differential Group Individual Responses to Training (ML TTB MEAN OF MIN)

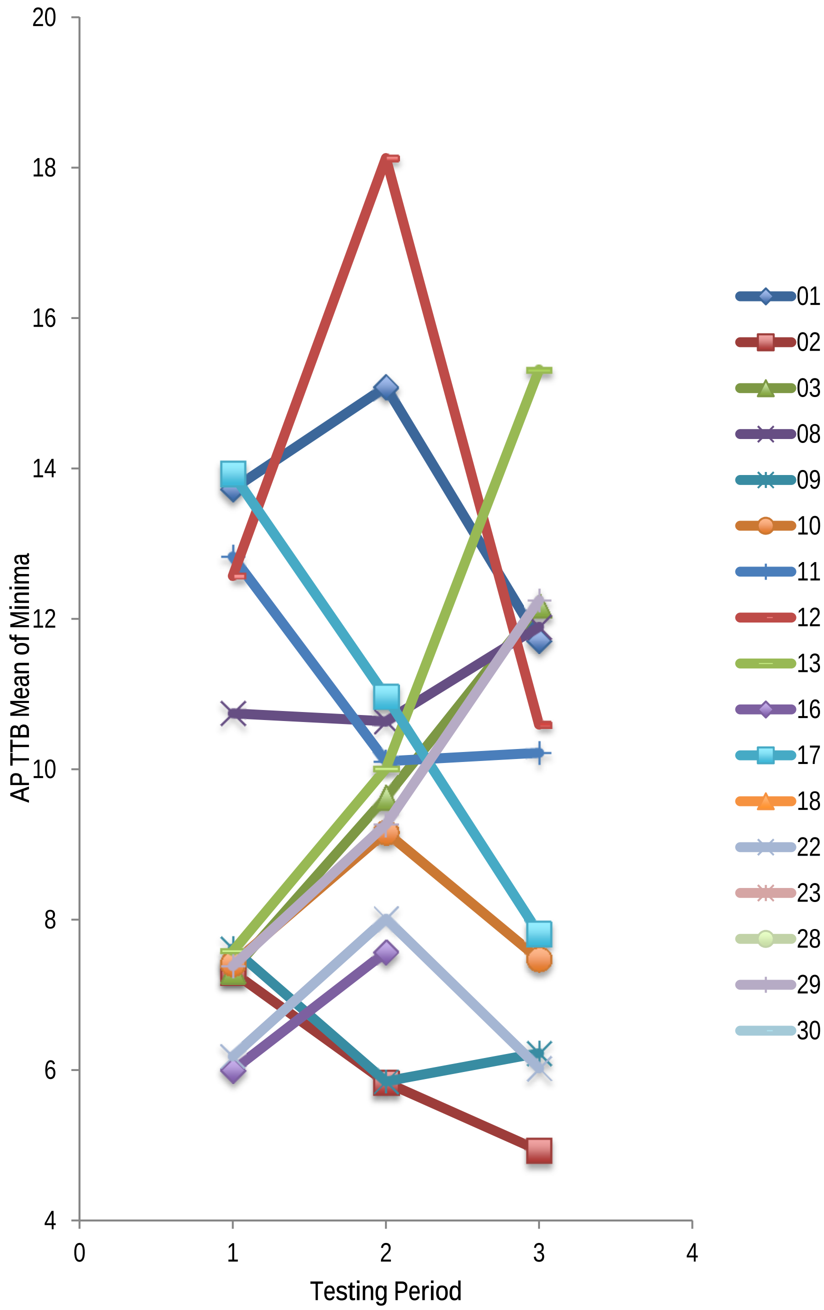

Figure 16. Traditional Group Individual Responses to Training (AP TTB MEAN OF MIN)

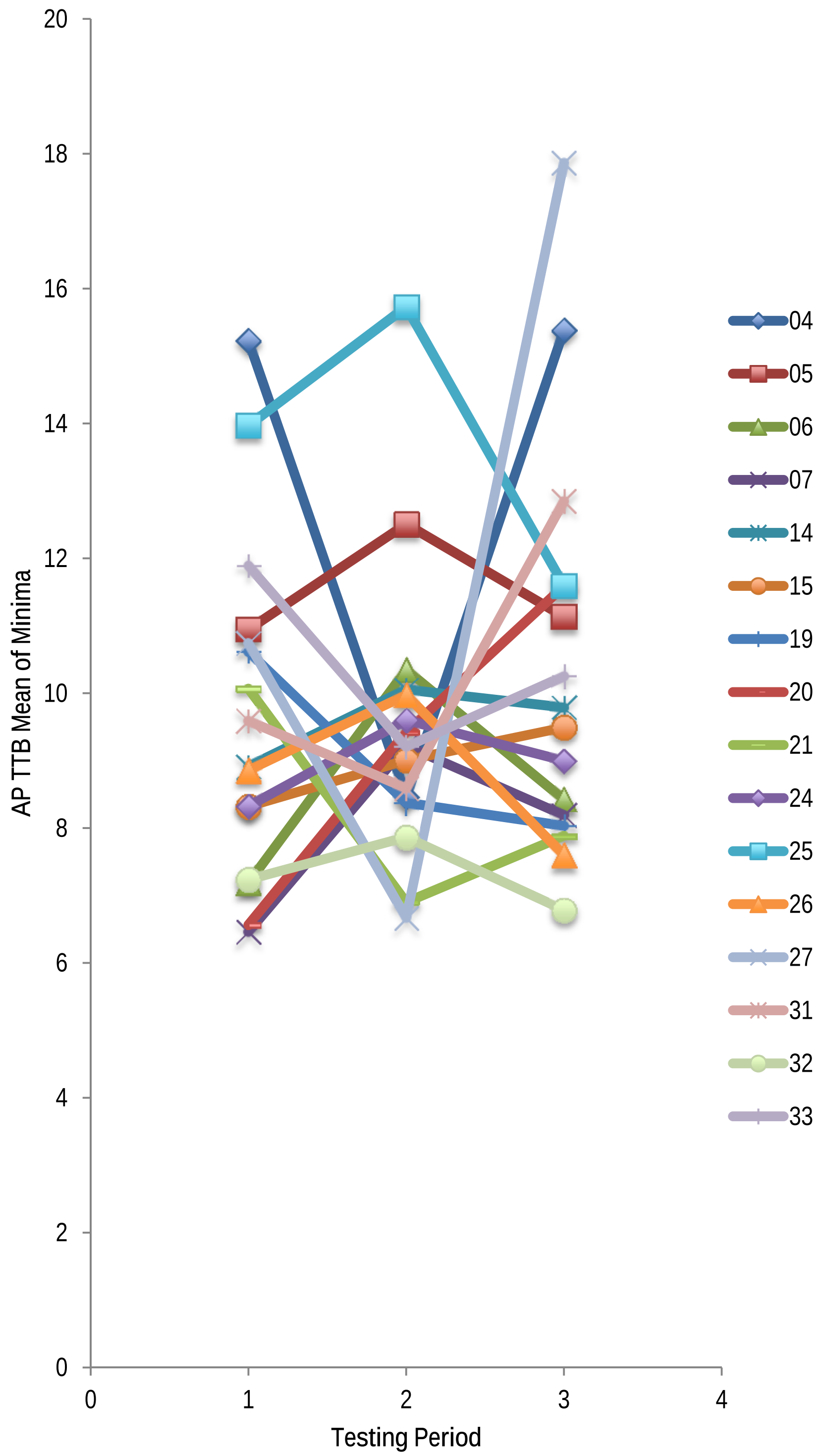

Figure 17. Differential Group Individual Responses to Training (AP TTB MEAN OF MIN)

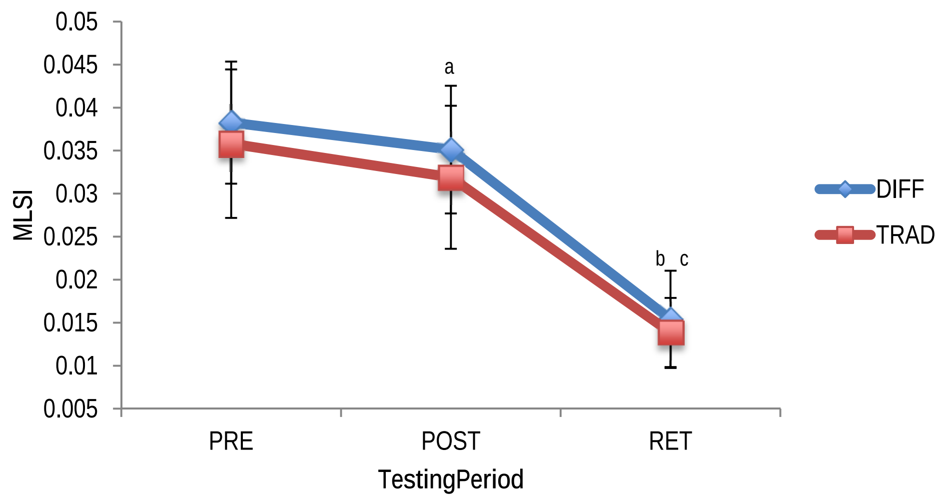

Figure 18. MLSI. [a] indicates significant difference from pre- to post-test, [b] indicates significant difference from post- to retention test, [c] indicates significant difference from pre- to retention test.

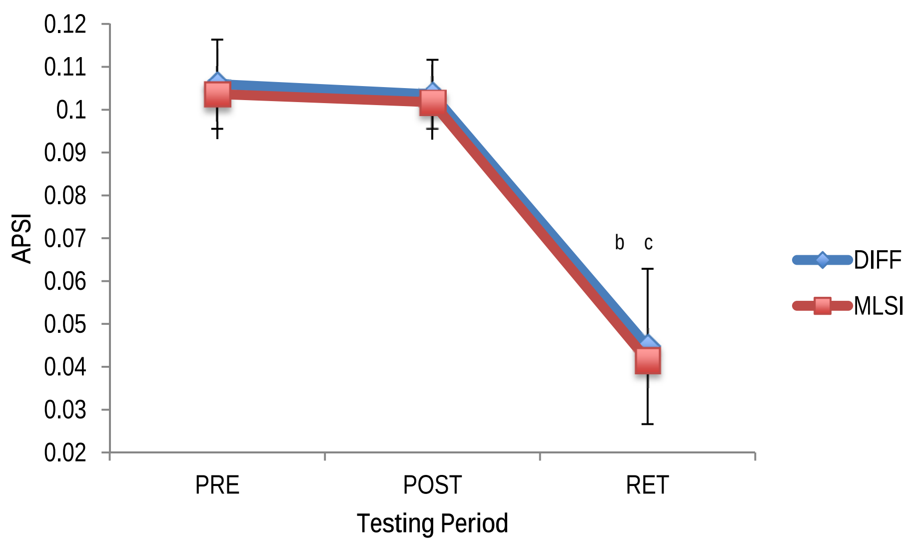

Figure 19. APSI. [b] indicates significant difference from post- to retention test, [c] indicates significant difference from pre- to retention test.

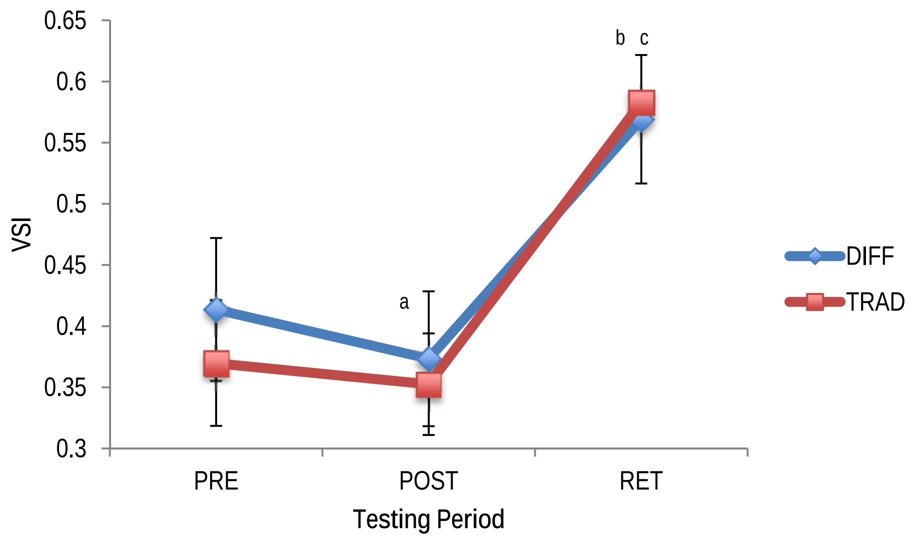

Figure 20. VSI. [a] indicates significant difference from pre- to post-test, [b] indicates significant difference from post- to retention test, [c] indicates significant difference from pre- to retention test.

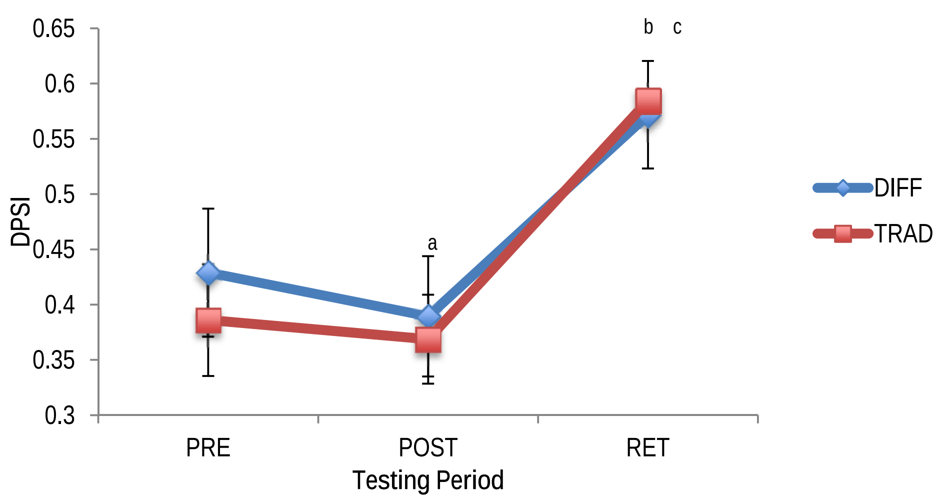

Figure 21. DPSI. [a] indicates significant difference from pre- to post-test, [b] indicates significant difference from post- to retention test, [c] indicates significant difference from pre- to retention test.

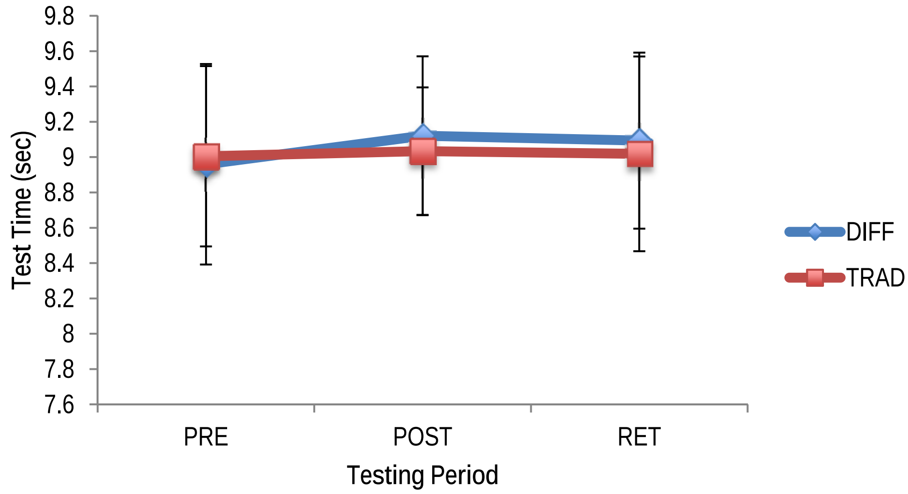

Figure 22. Arrowhead Agility Test (Right)

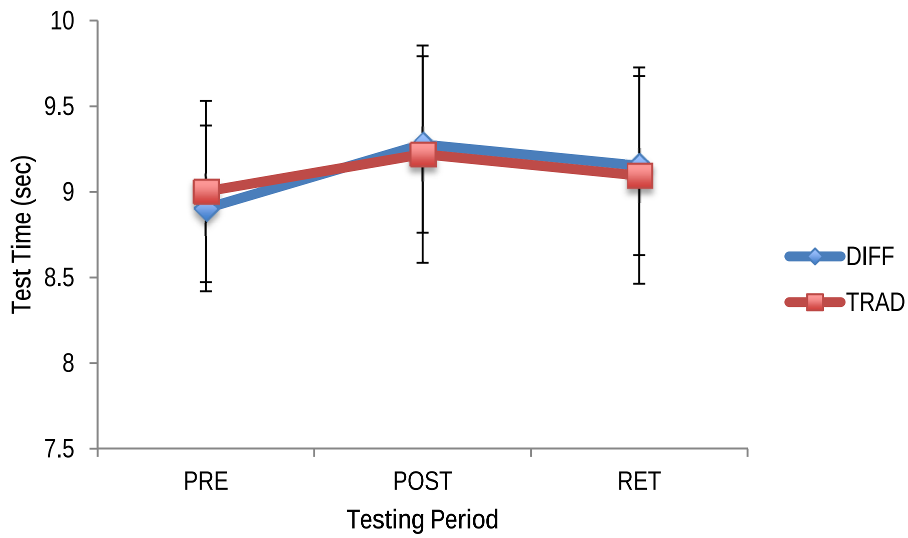

Figure 23. Arrowhead Agility Test (Left)

CHAPTER 6 – CONCLUSION

In conclusion, our results show that both the differential training and the traditional program had similar effects on balance. The only difference between groups in balance shown was during the static condition in the AP direction during the eyes closed condition, which is to be expected as the traditional group performed half of their training with eyes closed while the differential training group had their eyes open during all of their training.

Static balance in the ML direction during the eyes open condition improved for both groups. During the eyes closed condition, both groups improved initially, and then, during the retention test balance declined and was closer to the initial pre-test data. Dynamic balance showed improvements in the AP and ML directions but a decline in the vertical direction as well as the global postural control, as represented by the DPSI. Statistical tests showed an inverse relationship between the APSI and MLSI and the VSI and DPSI, which leads us to wonder whether DPSI is a good measure of global postural control. There were no significant changes in agility times across the three testing periods. Perhaps the Arrowhead Agility Test does not give us as much insight as planned. More research is needed to determine if the Arrowhead Agility Test can be used as a functional balance measure.

Overall, both programs showed improvements in balance in general, but clearly left some unanswered questions. Studies should be done to investigate the different measures of balance, especially the DPSI in time to stabilization measurements, as it is unclear if it is actually a global measurement of postural control. Also, future research should continue to examine the effects of differential training and how it affects the balance of individuals, especially a closer examination of the specific responses of individuals to the training. This information could lead to understanding of why certain individuals are more prone to chronic ankle injury than others, as it would allow better insight into how individuals cope with ankle injury and rehabilitation post injury. Also, it would inform clinicians as to which type of balance program should be used in order to increase balance in individuals.

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APPENDICIES

APPENDIX A: INFORMED CONSENT

CONSENT FORM

Project Title:	A Comparison of Two Different Balance Training Programs
Principal Investigator:	Sam Johnson, PhD, ATC
Student Researcher:	Jordyn Eisenhard, ATC
Co-Investigator(s):	Marc Norcross, PhD, ATC; Mark Hoffman, PhD, ATC; Natalie Swanson; Jason Arbour
Version Date:	01/24/2013

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1. WHAT IS THE PURPOSE OF THIS FORM?

This form contains information you will need to help you decide whether to be in this study or not. Please read the form carefully and ask the study team member(s) questions about anything that is not clear.

2. WHY IS THIS STUDY BEING DONE?

Ankle sprains are one of the most common injuries in sports. One way to decrease the risk of ankle sprains is with balance training. Balance training programs that have been shown to decrease ankle sprains consist of performing the same exercises repeated until error free. However, recent studies have shown that by changing and never repeating the exercises there is increased learning when compared to programs that repeat the same tasks. This type of training is called differential training. However, no one has studied a differential balance training program. Therefore, the purpose of this study is to compare two different types of balance programs: one based on repetition and one based on differential training (or never repeating). The aim is to determine if one type of balance training is better than the other. Up to 60 participants may be enrolled to take part in this study. This research will be used as part of a student master's thesis.

3. WHY AM I BEING INVITED TO TAKE PART IN THIS STUDY?

You are being invited to take part in this study because you are over the age of 18 and are:

1. Currently on the roster for the Oregon State University men's or women's intercollegiate soccer team and
2. Cleared to participate in both training and conditioning with your team

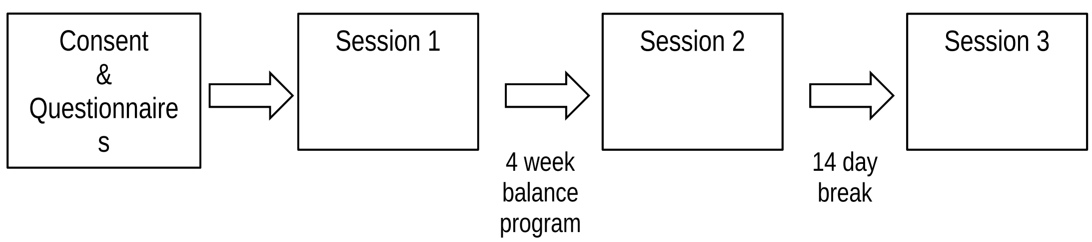
You cannot participate in this study if:

1. You have any current vestibular or balance disorders or
2. Have had a concussion within one month from the start of the study or
3. Are undergoing current lower extremity rehabilitation

4. WHAT WILL HAPPEN IF I PARTAKE IN THIS RESEARCH STUDY?

This study will involve 4 weeks of balance training that will be part of the warm-up of your conditioning program. It will be done 3 times per week and each session will take less than 10 minutes. You will be assigned to one of the two balance training programs after completing the initial testing.
There will be a consent meeting where if you agree to participate in the study you will fill out two questionnaires. There will also be three testing sessions in the Women's Building. These sessions will include tests of your balance, agility, and vertical jump.

- Session 1: Completed prior to beginning the four week balance training program
- Session 2: Completed following the four weeks of the balance training program
- Session 3: Completed 14 days after completion of the program.



Consent Meeting (~10 minutes)

- Consent, health history, and FADI forms

  You will report to either Jordyn Eisenhard's office in the Gill Coliseum Sports Medicine Facility or the Neuromechanics Laboratory in the Women's Building to consent to participate in the study. If you agree to participate in the study you will complete the written consent form, the health history form, and a survey to determine if you have chronic ankle instability (FADI). If you do not consent to being in the study no other information will be collected from you.

Session 1 Testing (~35 minutes)

All testing will be done in the Women's Building.

- Measure height, weight, leg dominance determination, and foot measurement (~ 5 minutes)

- Your height and weight will be measured with your shoes off. You will be asked what leg you would use to kick a penalty kick to determine your dominant leg. You will also have a measurement of your dominant foot taken by drawing an outline of your foot on a blank sheet of paper. Three small marks will be drawn with a marker on both sides of your foot and your second toe. These marks will be used to align your foot when your balance is tested.

- Static balance measurement (~5 minute)
  - You will stand on a force plate which is a piece of equipment that is embedded into the ground that measures the forces that you exert on the ground. You will be required to stand on the force plate on your kicking leg for 10 seconds with your eyes open for up to a total of six trials. You will then repeat this task with your eyes closed for up to a total of six trials. You will be given 30 seconds rest between each trial.

- Maximum vertical jump height measurement (~5 minutes)
  - You will put your shoes on and your maximum vertical jump height will be measured using a Vertec jump height measurement device. You will stand with your feet shoulder width apart and jump and touch as high as possible on the plastic measurement markers of the Vertec. You will perform up to six vertical jumps with 30 seconds rest between each jump. The highest jump will be used during the dynamic balance measure described in the next section.

- Dynamic balance measurement (~5 minutes)
  - Starting 70 cm from the force plate, you will jump off of both legs attempting to reach 50% of your maximum vertical jump height (as measured by the Vertec device) and land only on your kicking foot on the force plate. Once you land you will then continue to hold the single leg stance for 20 seconds. You will repeat this task for up to a total of six trials with30 seconds rest between each trial.

- Balance screening (~5 minutes)
  - You will also be screened to see what level you would start the traditional balance program. With your shoes off, you will try to maintain balance on your kicking leg for the specified time at each level. You will stop once you lose balance.

The levels are:

- Level 1: Arms out on hard floor for 30 seconds
- Level 2: Hands on hips on hard floor for 30 seconds
- Level 3: Arms out on foam pad for 30 seconds
- Level 4: Hands on hips on foam pad for 30 seconds
- Level 5: Hands on hips on foam pad for 60 seconds
- Level 6: Hands on hips on foam pad for 90 seconds

Losing balance is defined by any of the following:

- Touching down with your non-kicking leg
- Touching your non-kicking leg to your kicking leg
- Moving the foot of your kicking leg
- Moving the trunk to the side
- Removing either hand from your hip
- Moving your non-kicking leg backwards or to the side

- Arrowhead Agility Test (~10 minutes)
  - The agility test will require you to run around a series of 4 cones as fast as you can. You will have to change direction at multiple points in the test. You will run the test up to 5 times in each direction (no more than 10 total trials) with 60 seconds between each trial. The first two trials in each direction will be practice trials.

Balance Training Programs

1. Traditional balance program:

   In this program you will be asked to stand on your kicking leg in the following positions:

   - Level 1: Arms out on hard floor for 30 seconds
   - Level 2: Hands on hips on hard floor for 30 seconds
   - Level 3: Arms out on foam pad for 30 seconds
   - Level 4: Hands on hips on foam pad for 30 seconds
   - Level 5: Hands on hips on foam pad for 60 seconds
   - Level 6: Hands on hips on foam pad for 90 seconds

   Your goal is to perform the trial without:

- Touching down with your non-kicking leg
- Touching your non-kicking leg to your kicking leg
- Moving the foot of your kicking leg
- Moving the trunk to the side
- Removing either hand from your hip
- Moving your non-kicking leg backwards or to the side

At each session you will attempt 4 trials with your eyes open and 4 trials with your eyes closed. After each trial, you will be given 30 seconds rest. Once you are able to complete 4 trials without any of the mentioned errors, you will progress to the next level. The level you start the training at will be determined in the Session 1 testing described above. If you successfully complete Level 6 you will continue practicing at that level until the conclusion of the balance training portion of the study.

2. Differential training balance program:
   The differential training balance program will also consist of you standing on your kicking leg while performing a variety of other movements. These other movements will be of the non-kicking leg, the trunk, arms and/or head. These balance exercises will be done with a variety of speeds and rhythms. The same exercise will never be repeated during the course of the study so there will be no progression to different levels - just different exercises. There will also be no feedback provided to you on how well you performed the exercise.

Session 2 and 3 Testing (~26 minutes)

After you finish the balance training program, you will come back to the Women's Building for Session 2 and then again after at least 14 days after that for Session 3. These follow-up tests will consist of the same testing as Session 1 except for determining your leg dominance, foot measurement, or the balance screening.

- Measure height and weight (~3 min)
- Static balance measure (~5 minutes)
- Maximum vertical jump height (~3 minutes)
- Dynamic balance measure (~5 minutes)
- Arrowhead Agility Test (~10 minutes)

Storage and Future use of data or samples:

Because it is not possible for us to know what studies may be a part of our future work, we ask that you give permission now for us to use your personal information without being contacted about each future study. Future use of your information will be limited to studies about exercise, balance, agility, neuromuscular or athletic performance. If you agree now to future use of your personal information, but decide you would like to have your personal information removed from the research database, please contact Sam Johnson at sam.johnson@oregonstate.edu.

______You may store my data for use in future studies.
Initials

______ You may not store my data for use in future studies.
Initials

5. WHAT ARE THE RISKS AND POSSIBLE DISCOMFORTS OF THIS STUDY?

The risks of this study are minimal.

The balance testing procedures in this protocol have been done before in previous studies. The balance training exercises have been done in previous studies or are commonly done in the sports medicine setting with individuals rehabilitating injuries. Additionally, the balance training programs will be performed under the supervision of the research staff as well as OSU strength and conditioning staff. All of the staff has expertise in balance training. Although all tasks in the programs are self-paced, there is a possibility that you may not be able to complete the tasks. If this occurs, you will be instructed to regain balance and then continue the task. There is the possibility of you losing balance and slipping and/or falling, but this probability is believed to be low. If you are deemed to have chronic ankle instability, as defined by the FADI, you have a slight higher risk of slipping and/or falling. But all of the exercises are routine clinical practice both in the rehabilitation setting as well as the soccer field. Although unlikely, muscle soreness may occur. If at any time you feel uncomfortable and wish to stop the testing, you should inform the research staff and end the test.

The Arrowhead Agility Test measures your ability to change direction while running at a fast speed. There is a possibility that it would result in a muscle strain or other type of injury. In order to minimize this you will complete two practice trials each direction. If at any time you feel uncomfortable and wish to stop the testing, you should inform the research staff and end the test.

You will also be asked to jump at various points in this study during the testing sessions. We ask you to jump in order to measure your maximum vertical jump and to measure your balance once you have landed. There is a possibility that it would result in a muscle strain or other type of injury. You will have performed other balance tests prior to completing the jumping which should help reduce risk. If at any time you feel uncomfortable and wish to stop the testing, you should inform the research staff and end the test.

We have procedures in place to protect your privacy. However, there is a small risk that we could accidentally disclose information that identifies you. Please see the section "WHO WILL SEE THE INFORMATION I GIVE?" for our procedures to minimize your risk.

6. WHAT HAPPENS IF I AM INJURED?

Oregon State University has no program to pay for research-related injuries. If you think that you have been injured as a result from being in this study, please immediately contact the study personnel.

7. WHAT ARE THE BENEFITS OF THIS STUDY?

We do not know if you will benefit from being in this study. However, you may benefit because previous balance training studies have improved balance of participants.

8. WILL I BE PAID FOR BEING IN THIS STUDY?

You will not be paid for being in this research study.

9. WHO WILL SEE THE INFORMATION I GIVE?

The information you provide during this research study will be kept confidential to the extent permitted by law. Research records will be stored securely and only researchers will have access to the records. Federal regulatory agencies and the Oregon State University Institutional Review Board (a committee that reviews and approves research studies) may inspect and copy records pertaining to this research. Some of these records could contain information that personally identifies you.

To help protect your privacy, your name and contact information will be stored on one "master" document. All other information that we collect about you will not be directly associated with your name. Instead, we will use a unique identification code on data forms instead of your name. Your information will be stored either on a laboratory or researchers' password protected computer, on a computer or in a file a locked cabinet that is in the researchers' laboratory or office.

If the results of this project are published, your identity will not be made public.

10. WHAT OTHER CHOICES DO I HAVE IF I DO NOT PARTAKE IN THIS STUDY?

Participation in this study is voluntary. If you decide to participate, you are free to withdraw at any time without penalty. You will not be treated differently if you decide to stop taking part in the study. Your decision on participation in this study will not affect your relationship with the team, coaches, or sports medicine staff. If you choose not to participate in the study you will still take part in the training (as it is part of the team's warm-up), but your balance and agility will not be tested. If you choose to withdraw from this project before it ends, the researchers may keep information collected about you and this information may be included in study reports.

11. PARTICIPATION TERMINATION BY INVESTIGATOR:

If during the course of the study you meet any of the exclusion criteria (i.e., begin lower extremity rehabilitation, sustain a concussion, or are diagnosed with a balance or vestibular disorder you will be removed from the study). You will still be allowed to participate in the balance training programs, as it is part of your conditioning warm-up, but we will not collect any data after you become ineligible for the study.

12. WHO DO I CONTACT IF I HAVE QUESTIONS?

If you have any questions about this research project, please contact: Sam Johnson at sam.johnson@oregonstate.edu

If you have questions about your rights or welfare as a participant, please contact the Oregon State University Institutional Review Board (IRB) Office, at (541) 737-8008 or by email at IRB@oregonstate.edu

13. WHAT DOES MY SIGNATURE ON THIS CONSENT FORM MEAN?

Your signature indicates that this study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Do not sign after the expiration date: Delete this line only if the study is exempt. The IRB will insert the appropriate date when the consent form is approved.

Participant's Name (printed): ____

______________________________________ ____________________________

(Signature of Participant) (Date)

______________________________________ ____________________________

(Signature of Person Obtaining Consent) (Date)

APPENDIX B: HEALTH HISTORY QUESTIONAIRE

Health History Questionnaire

Participant Code: ________________________ Date: ___________________

Age: _____________________________

1. Do you have a balance and/or vestibular disorder? YES NO
2. Have you had a concussion in the past month? YES NO
3. Have you ever had a lower extremity injury? YES NO

   If yes, please list with approximate date: _______________________________________
4. Have you ever had lower extremity surgery? YES NO

   If yes, please list with approximate date: _______________________________________
5. Are you currently undergoing lower extremity rehabilitation? YES NO

   If yes, please list what for: ____

APPENDIX C: FADI

The Foot and Ankle Disability Index (FADI) with Sports Module Score

Standing	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Walking on even ground	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Walking on even ground without shoes	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Walking up hills	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Walking down hills	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Going up stairs	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Going down stairs	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Walking on uneven ground	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Stepping up and down curves	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Squatting	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Sleeping	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Coming up on your toes	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Walking initially	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Walking 5 minutes or less	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
Walking approximately 10 minutes	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do

Walking 15 minutes or greater
No difficulty at all   Slight difficulty   Moderate difficulty   Extreme difficulty   Unable to do

Home responsibilities
No difficulty at all   Slight difficulty   Moderate difficulty   Extreme difficulty   Unable to do

Activities of daily living
No difficulty at all   Slight difficulty   Moderate difficulty   Extreme difficulty   Unable to do

Personal care
No difficulty at all   Slight difficulty   Moderate difficulty   Extreme difficulty   Unable to do

Light to moderate work (standing, walking)
No difficulty at all   Slight difficulty   Moderate difficulty   Extreme difficulty   Unable to do

Heavy work (push/pulling, climbing, carrying)
No difficulty at all   Slight difficulty   Moderate difficulty   Extreme difficulty   Unable to do

Recreational activities
No difficulty at all   Slight difficulty   Moderate difficulty   Extreme difficulty   Unable to do

General level of pain
No pain   Mild   Moderate   Severe   Unbearable

Pain at rest
No pain   Mild   Moderate   Severe   Unbearable

Pain during your normal activity
No pain   Mild   Moderate   Severe   Unbearable

Pain first thing in the morning
No pain   Mild   Moderate   Severe   Unbearable

SPORTS MODULE

Running
No difficulty at all   Slight difficulty   Moderate difficulty   Extreme difficulty   Unable to do

Jumping
No difficulty at all   Slight difficulty   Moderate difficulty   Extreme difficulty   Unable to do

Landing
No difficulty at all   Slight difficulty   Moderate difficulty   Extreme difficulty   Unable to do

Squatting and stopping quickly
No difficulty at all   Slight difficulty   Moderate difficulty   Extreme difficulty   Unable to do

Cutting, lateral movements

No difficulty at all　Slight difficulty　Moderate difficulty　Extreme difficulty　Unable to do

Low-impact activities

No difficulty at all　Slight difficulty　Moderate difficulty　Extreme difficulty　Unable to do

Ability to perform activity with your normal technique

No difficulty at all　Slight difficulty　Moderate difficulty　Extreme difficulty　Unable to do

Ability to participate in you desired sport as long as you would like

No difficulty at all　Slight difficulty　Moderate difficulty　Extreme difficulty　Unable to do

APPENDIX D: DATA COLLECTION SHEET

Subject Number: ____________________

Initial Testing   Date: _________

Height (cm)		Weight (kg)		Dominant leg	
Max vertical jump height					
Agility test (sec)					

	T1	T2	T3	T4	T5	T6
TTB						
TTS						

Eyes Open	**Starting Level**	**Eyes Closed**	**Starting Level**
1o: arms out on hard floor		1c: arms out on hard floor	
2o: hands on hips on hard floor		2c: hands on hips on hard floor	
3o: arms out on foam pad		3c: arms out on foam pad	
4o: hands on hips on foam pad		4c: hands on hips on foam pad	
5o: hands on hips on foam pad (60 seconds)		5c: hands on hips on foam pad (60 seconds)	
6o: hands on hips on foam pad (90 seconds)		6c: hands on hips on foam pad (90 seconds)	

Post Test   Date: _________

Height (cm)			Weight (kg)		
Max vertical jump height					
Agility test (sec)					

	T1	T2	T3	T4	T5	T6
TTB						
TTS						

Retention Test   Date: _________

Height (cm)			Weight (kg)		
Max vertical jump height					
Agility test (sec)					

	T1	T2	T3	T4	T5	T6
TTB						
TTS						

APPENDIX E: DIFFERENTIAL TRAINING PROGRAM

DAY 1	DAY 2	DAY 3
Upright row	Bicep curl	Stand in dorsiflex with medball around the world
Lateral side bend to the L hands on hips	Low squat with finger to nose	Trunk circles counter clockwise fast
Stand in dorsiflexion	Stand on heel with lateral bending	Valgus stance
Hip abd/add with jumping jack arms	Internal rotation stance	Anterior/posterior leg swings fast with military press
Half circle leg swings fast with alt arms military press	Quad stretch	Tricep ext
Touch arm to stance foot	Leg circle counter clockwise with arm circles counter clockwise	Posterior reach
Leg circles clockwise slow with arms straight up	Glute stretch stance	Anterior reach with windmill arms
High kick	Oblique crunch	Stand on toes with hip circles clockwise
DAY 4	DAY 5	DAY 6
Toe curls	Leg circles slow	Hold high knee with alternating arm abd
Lateral anterior reach	Oblique crunch in inverted ankle stance	Touch non stance foot to arm with high kick (hamstring stretch)
Medicine ball toss to self	Volleying motion	Stand in dorsiflexion with hip counterclockwise circles
High knees with clapping arms	Medicine ball around the world	Squats with abd arms
Butt kickers with trunk flexion	Stand on heels	Stand in planterflexion
Alphabet hips backward with arms criss crossed on chest	Military press	Anterior/posterior leg swings slow
Bent over rows	Jumping jack arms with squats	Lateral bend to right with arms overhead
Trunk ext with hands over head	RDL w/ hand on hips	Tree pose

DAY 7	DAY 8	DAY 9
Stand in inversion with medball toss to self	Bent over row with posterior reach	Arm abduction
Arms overhead	Stand on toes	Windmill arms with leg in tree pose
Sprinkler arms (left arm)	Toe curls with trunk clockwise circles	Valgus stance with arm counterclockwise small circles
Stand on heels with lateral side bends	Leg circles counter clockwise fast	Running motion
Medial/lateral leg swings fast	Passing motion with tree pose arms	Jumping jack arms with hip abduction
Squat position with jabbing arms	Alphabet with hips	Stand in inversion
Externally rotated stance	Arm circles big forward	Shooting motion
Arms behind head and butt kickers slow	Trunk circles clockwise slow with arms abd	Finger to nose
DAY 10	DAY 11	DAY 12
Windmill arms	Toe curls while touching ground	Criss cross jabbing arms
Butt kickers to high knee with touch between	External rotated stance leg with rows	Calf raises with bicep curl
Trunk flex/ext fast	Medial/lateral leg swings fast with head lateral bends	Lateral side bend slow
Lateral bend to right with hands up with bent non stance leg	Basketball shot	Gate openers with finger to nose
Gate closers	Calf raises	Butt kickers fast
Hip circles counter clockwise fast with tricep ext	High knee slow	Lateral posterior reach with arms up
Squats	Hip circles counter clockwise slow	Stand in eversion
Toe raises	Jabbing arms	Tripod stance

PPENDIX F: DATA

EYES OPEN PRETEST																
SUBJECT	GROUP	ML TTB Abs MIN_PRE	Mean ML TTB_PRE	SD ML TTB_PRE	AP TTB Abs Min_PRE	Mean AP TTB_PRE	SD AP TTB_PRE	COPx Max_PRE	COPx Min_PRE	Mean COPx V_PRE	SD COPx Excursions _PRE	COPy Max_PRE	COPy Min_PRE	Mean COPy V_PRE	SD COPy Excursions _PRE
01	T	0.039	4.671	8.745	0.039	13.727	15.880	22.032	0.096	4.421	1.713	36.072	0.156	5.506	2.821
02	T	0.052	2.893	8.198	0.051	7.304	10.254	19.365	0.084	5.981	1.455	33.228	0.142	6.287	2.451
03	T	0.044	2.785	3.930	0.049	7.322	9.962	20.759	0.089	5.449	1.612	34.129	0.147	6.516	2.453
04	D	0.034	3.797	6.525	0.042	15.227	21.692	21.308	0.093	4.321	1.798	34.269	0.148	5.374	2.553
05	D	0.037	5.882	12.652	0.042	10.946	15.205	21.110	0.091	4.124	1.830	34.562	0.149	5.836	2.748
06	D	0.043	2.907	3.397	0.061	7.187	8.283	20.485	0.088	4.820	1.536	32.136	0.137	6.244	2.466
07	D	0.042	2.162	5.033	0.047	6.464	8.360	21.463	0.091	6.472	1.614	34.863	0.151	6.661	2.705
08	T	0.034	2.209	3.066	0.051	10.743	15.445	21.615	0.092	5.476	1.812	33.213	0.143	5.966	2.561
09	T	0.034	2.927	6.156	0.050	7.618	8.672	22.101	0.096	5.933	1.846	34.139	0.148	6.455	2.539
10	T	0.041	2.201	2.705	0.067	7.416	10.559	21.044	0.091	5.233	1.655	31.118	0.134	6.257	2.219
11	T	0.042	2.798	3.508	0.047	12.829	23.358	20.516	0.089	4.721	1.517	33.859	0.146	5.574	2.575
12	T	0.036	3.653	11.230	0.043	12.572	17.790	21.320	0.092	4.693	1.710	34.740	0.150	6.212	2.566
13	T	0.038	4.308	10.296	0.050	7.580	9.742	21.740	0.092	5.448	1.845	34.176	0.147	7.144	2.696
14	D	0.037	5.752	11.914	0.054	8.913	11.459	21.593	0.093	4.584	1.695	32.914	0.141	5.662	2.576
15	D	0.055	1.760	2.881	0.048	8.322	14.959	19.605	0.085	6.592	1.475	34.419	0.150	6.834	2.561
16	T	0.037	2.824	4.046	0.047	5.999	8.385	21.487	0.093	5.889	1.873	34.961	0.150	7.732	2.749
17	T	0.047	4.252	6.226	0.057	13.931	19.018	19.693	0.085	3.865	1.498	31.784	0.137	5.083	2.542
18	T	0.024	2.038	3.016	0.053	5.776	10.702	22.395	0.096	5.661	1.948	32.582	0.142	6.971	2.556

19	D	0.039	2.903	5.183	0.064	10.617	16.069	21.333	0.090	5.803	1.688	32.125	0.136	5.723	2.441
20	D	0.031	2.631	4.256	0.042	6.565	7.508	21.812	0.094	5.467	1.743	34.842	0.149	6.151	2.674
21	D	0.031	3.939	6.384	0.046	10.068	12.220	21.676	0.093	4.582	1.976	33.750	0.146	5.730	2.491
22	T	0.032	3.358	5.939	0.060	6.184	6.887	21.894	0.095	5.302	1.882	32.338	0.140	6.617	2.343
23	T	0.043	2.788	3.840	0.052	11.873	14.493	21.186	0.091	5.335	1.784	34.277	0.147	5.609	2.583
24	D	0.042	4.080	6.547	0.048	8.323	11.131	20.415	0.088	4.304	1.518	31.964	0.138	5.401	2.393
25	D	0.029	4.368	8.430	0.051	13.970	27.865	21.996	0.095	4.178	1.875	33.030	0.142	5.365	2.528
26	D	0.042	3.057	7.230	0.044	8.858	15.770	21.149	0.091	5.458	1.677	35.037	0.151	6.378	2.593
27	D	0.031	2.425	4.351	0.042	10.746	16.582	22.361	0.096	5.732	1.779	36.246	0.157	6.149	2.754
28	T	0.039	3.356	4.742	0.051	9.376	10.910	21.444	0.093	4.778	1.785	33.349	0.145	5.879	2.601
29	T	0.025	2.589	3.415	0.048	7.384	9.173	22.066	0.095	4.948	1.914	32.863	0.141	5.792	2.471
30	T	0.055	3.185	6.726	0.060	10.302	16.910	19.134	0.083	4.780	1.502	31.703	0.137	5.750	2.353
31	D	0.041	2.778	5.197	0.059	9.589	12.459	20.869	0.090	4.993	1.592	31.610	0.136	5.403	2.301
32	D	0.035	2.605	3.239	0.049	7.235	8.750	21.727	0.094	5.569	1.883	34.127	0.148	6.763	2.523
33	D	0.044	4.799	8.962	0.051	11.889	19.281	19.152	0.082	4.094	1.490	35.399	0.143	5.855	2.607

EYES OPEN POST TEST															
SUBJECT	GROUP	ML TTB Abs MIN_POST	Mean ML TTB_POST	SD ML TTB_POST	AP TTB Abs Min_POST	Mean AP TTB_POST	SD AP TTB_POST	COPx Max_POST	COPx Min_POST	Mean COPx V_POST	SD COPx Excursions_ POST	COPy Max_POST	COPy Min_POST	Mean COPy V_POST	SD COPy Excursions_ POST
01	T	0.038	4.683	6.290	0.045	15.085	23.506	22.255	0.096	4.661	1.735	34.581	0.149	5.353	2.614
02	T	0.044	1.513	2.303	0.047	5.837	8.212	20.826	0.088	6.907	1.641	34.217	0.147	7.648	2.642
03	T	0.038	3.153	4.304	0.056	9.625	14.168	21.537	0.093	4.750	1.792	32.540	0.139	5.806	2.413
04	D	0.040	3.271	4.330	0.046	8.469	13.172	20.537	0.089	4.572	1.651	33.443	0.143	5.779	2.637
05	D	0.039	5.810	10.528	0.048	12.507	24.317	20.834	0.090	3.975	1.728	33.092	0.142	5.599	2.603
06	D	0.041	3.906	5.747	0.061	10.346	17.894	20.734	0.089	4.361	1.613	31.722	0.137	6.095	2.486
07	D	0.036	2.757	3.899	0.043	9.220	16.403	22.049	0.095	5.295	1.808	35.877	0.156	6.266	2.697
08	T	0.026	2.161	3.370	0.051	10.638	13.341	22.473	0.096	5.523	2.067	33.446	0.144	5.541	2.561

09	T	0.033	2.435	4.750	0.055	5.850	5.903	22.122	0.096	6.004	1.834	33.053	0.143	6.529	2.642
10	T	0.048	5.170	8.014	0.070	9.164	13.194	19.861	0.086	4.275	1.474	30.301	0.131	5.785	2.203
11	T	0.037	2.902	3.658	0.050	10.106	11.738	21.248	0.092	4.951	1.679	33.182	0.143	5.595	2.522
12	T	0.037	4.234	7.366	0.051	12.929	16.086	21.128	0.091	4.401	1.639	32.870	0.142	5.204	2.418
13	T	0.036	3.183	5.507	0.050	10.011	17.069	21.643	0.093	5.125	1.762	34.227	0.147	6.024	2.678
14	D	0.043	4.568	5.977	0.061	10.053	12.152	20.689	0.090	4.521	1.579	31.314	0.136	5.556	2.456
15	D	0.037	2.330	4.081	0.050	9.006	11.060	21.930	0.094	6.420	1.710	33.764	0.147	6.217	2.536
16	T	0.046	2.998	4.293	0.056	7.572	10.823	19.236	0.083	4.769	1.453	32.920	0.142	6.218	2.481
17	T	0.026	2.920	4.266	0.057	10.970	11.035	22.521	0.097	4.666	2.081	31.786	0.137	5.357	2.518
18	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
19	D	0.048	3.879	8.172	0.058	8.375	7.515	19.923	0.087	4.699	1.553	32.639	0.142	5.653	2.567
20	D	0.039	3.131	3.502	0.046	9.422	13.106	20.777	0.090	4.483	1.694	33.771	0.146	5.714	2.723
21	D	0.027	2.462	2.944	0.053	6.899	7.689	22.170	0.095	5.314	1.892	32.453	0.140	5.981	2.431
22	T	0.037	2.775	3.516	0.062	8.013	14.123	21.179	0.092	5.508	1.777	32.042	0.137	6.687	2.481
23	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
24	D	0.040	3.367	5.451	0.048	9.599	14.444	20.682	0.089	4.616	1.677	31.908	0.137	5.487	2.378
25	D	0.031	6.126	12.176	0.048	13.732	18.252	21.812	0.094	4.067	1.974	33.610	0.146	5.426	2.493
26	D	0.045	2.933	4.328	0.048	9.975	14.720	20.685	0.089	5.074	1.620	34.181	0.147	5.893	2.580
27	D	0.035	2.608	3.634	0.053	6.666	9.548	21.903	0.095	5.488	1.777	33.596	0.146	6.502	2.553
28	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
29	T	0.033	2.165	2.824	0.046	9.267	16.610	21.193	0.091	5.002	1.769	33.298	0.145	6.087	2.411
30	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
31	D	0.040	3.923	6.194	0.066	8.589	10.841	20.910	0.091	4.748	1.616	30.413	0.130	5.506	2.257
32	D	0.039	2.609	4.233	0.057	7.865	12.624	21.235	0.092	5.237	1.707	32.417	0.140	6.197	2.370
33	D	0.023	3.766	5.284	0.058	9.205	12.494	22.720	0.098	4.832	2.032	34.420	0.137	6.237	2.478

EYES OPEN RETENTION TEST															
SUBJECT	GROUP	ML TTB Abs MIN_RET	Mean ML TTB_RET	SD ML TTB_RET	AP TTB Abs Min_RET	Mean AP TTB_RET	SD AP TTB_RET	COPx Max_RET	COPx Min_RET	Mean COPx V_RET	SD COPx Excursions_RET	COPy Max_RET	COPy Min_RET	Mean COPy V_RET	SD COPy Excursions_RET
01	T	0.047	5.364	7.701	0.045	11.714	14.212	20.847	0.090	4.206	1.696	34.469	0.149	5.441	2.650
02	T	0.049	2.587	6.429	0.056	4.931	7.730	19.068	0.082	5.647	1.422	32.253	0.139	7.097	2.551
03	T	0.052	3.815	6.788	0.054	12.186	18.885	18.957	0.082	4.117	1.454	32.981	0.142	5.672	2.510
04	D	0.038	3.892	8.764	0.050	15.384	23.541	18.890	0.081	4.066	1.473	32.506	0.140	5.186	2.493
05	D	0.034	5.625	10.073	0.047	11.135	17.087	21.541	0.093	4.081	1.856	33.343	0.143	5.727	2.606
06	D	0.036	2.750	3.530	0.051	8.423	12.611	21.508	0.092	4.855	1.666	33.734	0.145	6.266	2.572
07	D	0.040	2.706	3.297	0.043	8.190	9.208	21.456	0.092	5.468	1.734	35.803	0.154	6.400	2.683
08	T	0.036	3.815	7.681	0.054	11.898	15.693	21.249	0.092	4.799	1.789	32.627	0.141	5.529	2.608
09	T	0.038	1.887	3.618	0.057	6.226	6.702	21.610	0.095	6.647	1.963	32.924	0.141	6.498	2.500
10	T	0.038	3.526	6.010	0.066	7.478	10.239	21.366	0.092	4.565	1.749	30.934	0.134	6.171	2.348
11	T	0.037	2.749	3.143	0.056	10.219	14.481	21.147	0.091	4.905	1.780	31.944	0.136	5.640	2.470
12	T	0.034	4.134	6.448	0.047	10.595	20.198	21.506	0.092	4.588	1.748	33.727	0.145	5.654	2.545
13	T	0.038	3.389	5.265	0.051	15.313	28.639	21.241	0.092	4.870	1.619	33.985	0.146	5.902	2.711
14	D	0.048	5.284	8.715	0.056	9.789	13.956	20.068	0.086	4.216	1.574	32.344	0.140	5.659	2.563
15	D	0.053	3.475	5.479	0.047	9.493	15.551	19.627	0.084	5.317	1.523	34.584	0.149	6.100	2.609
16	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
17	T	0.036	4.147	6.028	0.055	7.814	7.070	21.155	0.091	4.402	1.788	32.248	0.139	5.410	2.765
18	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
19	D	0.035	3.972	11.453	0.061	8.033	10.480	21.691	0.095	5.307	1.733	32.200	0.139	6.443	2.511
20	D	0.034	4.752	6.870	0.049	11.589	22.145	21.412	0.092	4.336	1.919	33.089	0.142	5.590	2.849
21	D	0.032	2.084	2.501	0.049	7.881	8.879	21.533	0.093	5.082	1.881	33.097	0.143	5.987	2.502
22	T	0.039	3.205	5.129	0.061	6.028	8.680	21.019	0.090	5.400	1.670	32.142	0.138	7.072	2.524
23	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---

24	D	0.032	4.254	6.481	0.051	8.998	14.569	21.695	0.094	4.159	1.721	31.257	0.134	5.228	2.388
25	D	0.036	6.263	11.149	0.047	11.595	16.059	21.206	0.091	4.029	1.625	33.895	0.146	5.420	2.551
26	D	0.043	4.332	9.448	0.047	7.597	9.298	20.884	0.090	5.226	1.579	34.183	0.148	6.066	2.579
27	D	0.036	4.056	6.236	0.051	17.864	23.217	21.613	0.094	4.803	1.687	33.927	0.146	5.717	2.539
28	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
29	T	0.038	4.851	11.027	0.046	12.249	24.639	20.565	0.089	4.248	1.560	33.290	0.143	5.568	2.513
30	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
31	D	0.044	2.679	4.002	0.062	12.851	42.403	20.413	0.088	5.164	1.542	31.027	0.135	5.874	2.263
32	D	0.039	3.899	5.574	0.048	6.785	8.391	21.189	0.091	4.666	1.740	34.459	0.148	6.428	2.702
33	D	0.024	3.326	4.856	0.047	10.254	13.450	22.614	0.097	4.735	2.026	34.127	0.146	5.936	2.713

EYES CLOSED PRE TEST															
SUBJECT	GROUP	ML TTB Abs MIN_RET	Mean ML TTB_RET	SD ML TTB_RET	AP TTB Abs Min_RET	Mean AP TTB_RET	SD AP TTB_RET	COPx Max_RET	COPx Min_RET	Mean COPx V_RET	SD COPx Excursions_ RET	COPy Max_RET	COPy Min_RET	Mean COPy V_RET	SD COPy Excursions_ RET
01	T	0.039	2.099	2.831	0.041	6.938	9.232	22.602	0.096	6.955	1.791	35.473	0.152	7.054	2.910
02	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
03	T	0.043	1.307	1.882	0.035	4.001	4.882	21.817	0.089	7.968	1.576	37.382	0.159	8.833	2.752
04	D	0.035	1.649	2.803	0.038	4.091	6.087	21.400	0.092	6.259	1.772	35.331	0.152	8.443	2.837
05	D	0.029	2.466	5.134	0.043	4.835	5.539	22.091	0.094	5.817	2.053	34.327	0.148	7.508	2.590
06	D	0.031	1.477	2.669	0.059	2.820	3.054	22.041	0.097	8.960	1.759	35.076	0.138	10.463	2.435
07	D	0.032	1.299	2.018	0.039	3.151	3.325	22.436	0.097	8.847	1.745	36.602	0.158	9.810	2.898
08	T	0.038	1.544	1.499	0.047	4.998	7.998	22.187	0.090	6.555	1.678	34.611	0.148	8.477	2.634
09	T	0.040	1.923	3.083	0.046	4.962	7.520	22.121	0.090	8.377	1.606	35.939	0.151	8.452	2.577
10	T	0.044	1.834	2.766	0.064	4.988	7.939	20.969	0.089	6.708	1.604	31.509	0.137	9.792	2.307
11	T	0.032	1.322	1.910	0.045	3.860	5.425	21.835	0.093	7.817	1.957	34.166	0.148	8.734	2.637
12	T	0.026	1.272	2.691	0.050	2.996	3.750	22.501	0.096	8.724	2.009	33.492	0.146	9.554	2.461
13	T	0.044	1.887	3.365	0.050	3.766	3.979	20.569	0.089	7.477	1.558	34.128	0.148	8.270	2.651

14	D	0.041	1.238	1.423	0.045	4.681	8.939	21.614	0.092	7.581	1.654	34.837	0.149	8.569	2.562
15	D	0.043	1.294	2.112	0.044	4.437	6.596	21.658	0.087	8.524	1.734	35.522	0.152	8.781	2.602
16	T	0.025	1.716	2.850	0.061	2.745	3.772	23.009	0.099	8.258	2.030	34.892	0.142	12.403	2.557
17	T	0.033	1.260	2.116	0.049	4.015	5.384	20.161	0.087	7.237	1.576	33.665	0.143	8.511	2.567
18	T	0.023	1.087	1.325	0.058	3.848	11.672	22.597	0.096	8.771	2.018	34.325	0.139	11.828	2.485
19	D	0.034	1.060	1.598	0.059	4.870	8.969	21.946	0.092	9.124	1.855	34.395	0.137	8.610	2.514
20	D	0.024	1.171	1.541	0.038	2.756	3.517	22.523	0.098	8.578	1.868	35.898	0.154	9.990	2.935
21	D	0.033	1.286	1.999	0.039	4.255	4.853	21.695	0.091	8.158	1.848	35.454	0.152	7.807	2.651
22	T	0.039	1.518	2.634	0.061	3.570	5.087	21.257	0.088	8.372	1.820	32.270	0.139	9.348	2.413
23	T	0.039	1.685	2.075	0.047	4.197	6.545	21.760	0.093	7.485	1.701	35.935	0.150	9.474	2.721
24	D	0.027	1.502	2.299	0.044	2.403	3.089	22.176	0.097	7.628	1.825	32.970	0.141	9.066	2.475
25	D	0.023	2.384	5.896	0.055	5.019	7.747	22.897	0.098	7.285	1.988	32.970	0.138	7.914	2.554
26	D	0.047	1.400	2.508	0.039	2.954	4.648	21.941	0.088	10.017	1.753	36.343	0.154	10.082	2.683
27	D	0.029	0.780	1.226	0.039	4.379	8.023	22.514	0.099	10.361	1.820	36.763	0.159	9.921	2.867
28	T	0.038	2.143	3.920	0.042	4.463	6.567	21.584	0.094	7.642	1.840	35.573	0.153	8.521	2.770
29	T	0.031	1.561	2.869	0.048	3.797	5.135	21.799	0.093	7.843	1.722	34.024	0.143	8.674	2.454
30	T	0.052	2.264	3.250	0.053	7.172	14.057	20.298	0.080	6.040	1.418	34.015	0.144	10.228	2.640
31	D	0.034	1.385	2.274	0.055	3.921	5.253	21.943	0.092	8.115	1.778	32.320	0.139	7.890	2.365
32	D	0.018	0.944	1.215	0.062	2.222	2.909	23.723	0.102	10.300	1.979	33.907	0.137	10.850	2.238
33	D	0.041	2.300	4.856	0.046	6.287	11.011	20.021	0.088	6.409	1.610	34.818	0.149	7.840	2.630

EYES CLOSED POST TEST															
SUBJECT	GROUP	ML TTB Abs MIN_RET	Mean ML TTB_RET	SD ML TTB_RET	AP TTB Abs Min_RET	Mean AP TTB_RET	SD AP TTB_RET	COPx Max_RET	COPx Min_RET	Mean COPx V_RET	SD COPx Excursions_ RET	COPy Max_RET	COPy Min_RET	Mean COPy V_RET	SD COPy Excursions_ RET
01	T	0.038	2.042	2.453	0.046	4.729	4.753	22.170	0.096	6.746	1.724	34.089	0.148	7.218	2.745
02	T	0.039	1.546	2.765	0.051	3.395	5.141	22.438	0.093	9.498	1.839	33.241	0.143	10.240	2.550

03	T	0.041	2.644	4.892	0.055	4.786	6.070	21.498	0.092	6.811	1.634	33.092	0.140	8.208	2.442
04	D	0.036	2.235	5.456	0.044	3.186	4.011	21.563	0.090	7.306	1.780	34.342	0.147	9.130	2.582
05	D	0.034	3.070	9.267	0.045	4.796	7.363	21.487	0.093	6.004	1.893	33.874	0.147	8.037	2.574
06	D	0.036	1.208	1.405	0.053	3.794	4.622	21.655	0.095	7.888	1.680	34.671	0.144	9.852	2.575
07	D	0.030	1.547	2.838	0.055	4.256	6.761	22.804	0.097	8.625	1.966	33.766	0.143	8.989	2.566
08	T	0.035	1.327	2.030	0.052	6.161	7.613	21.650	0.092	7.409	1.857	33.419	0.143	7.332	2.547
09	T	0.034	1.750	2.808	0.050	3.780	4.529	22.047	0.095	7.627	1.738	34.077	0.147	8.890	2.633
10	T	0.049	3.227	6.713	0.067	4.004	4.612	19.939	0.085	6.145	1.536	32.169	0.134	7.990	2.332
11	T	0.034	2.456	4.812	0.055	4.617	6.215	21.787	0.093	7.323	1.806	32.488	0.139	7.823	2.492
12	T	0.033	2.345	3.630	0.045	6.911	9.886	21.629	0.094	5.732	1.802	34.007	0.148	6.523	2.660
13	T	0.039	1.844	3.007	0.048	4.612	5.875	21.375	0.092	6.810	1.694	34.433	0.149	7.964	2.750
14	D	0.049	1.517	2.639	0.051	4.358	4.560	20.418	0.086	7.057	1.542	33.444	0.145	7.624	2.538
15	D	0.053	1.850	3.385	0.042	3.651	4.975	20.706	0.083	8.444	1.499	35.677	0.155	10.160	2.697
16	T	0.030	1.834	5.861	0.058	4.167	7.550	20.515	0.085	8.121	1.552	33.223	0.140	9.801	2.400
17	T	0.027	1.331	1.885	0.062	5.161	7.676	22.343	0.095	7.471	1.887	32.169	0.135	7.532	2.430
18	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
19	D	0.045	1.827	3.376	0.059	7.225	13.135	20.939	0.088	7.247	1.684	33.066	0.141	7.203	2.487
20	D	0.038	1.462	1.971	0.046	3.005	3.195	21.572	0.090	7.346	1.667	34.706	0.145	9.351	2.654
21	D	0.029	1.416	2.788	0.058	2.603	2.646	22.258	0.092	8.336	1.824	31.940	0.134	9.356	2.403
22	T	0.031	1.734	3.180	0.062	3.918	5.027	22.120	0.095	7.402	1.861	31.723	0.137	8.864	2.441
23	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
24	D	0.027	1.899	5.081	0.047	2.766	4.723	22.371	0.093	7.871	1.973	32.756	0.139	9.983	2.422
25	D	0.037	2.469	7.825	0.047	5.937	9.920	21.232	0.090	6.842	1.780	34.301	0.147	7.975	2.729
26	D	0.046	2.940	5.019	0.041	4.444	7.573	21.318	0.089	8.139	1.671	35.985	0.154	9.710	2.599
27	D	0.027	1.486	2.388	0.055	3.957	6.111	23.143	0.097	8.701	1.891	33.073	0.143	9.003	2.457
28	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
29	T	0.034	1.835	4.594	0.049	3.434	4.229	21.377	0.091	6.904	1.680	33.644	0.141	8.801	2.399
30	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
31	D	0.045	2.205	3.657	0.075	3.906	5.871	21.380	0.088	6.689	1.506	30.349	0.124	8.378	2.204

32	D	0.015	1.098	2.120	0.049	2.161	2.328	24.074	0.100	10.464	2.098	34.131	0.142	11.385	2.394
33	D	0.030	2.158	3.581	0.041	3.912	5.282	21.988	0.097	6.814	1.867	35.586	0.153	9.286	2.775

EYES CLOSED RETENTION TEST															
SUBJECT	GROUP	ML TTB Abs MIN_RET	Mean ML TTB_RET	SD ML TTB_RET	AP TTB Abs Min_RET	Mean AP TTB_RET	SD AP TTB_RET	COPx Max_RET	COPx Min_RET	Mean COPx V_RET	SD COPx Excursions_ RET	COPy Max_RET	COPy Min_RET	Mean COPy V_RET	SD COPy Excursions_ RET
01	T	0.043	2.656	5.703	0.048	7.225	10.519	21.778	0.093	6.422	1.690	33.665	0.146	6.843	2.686
02	T	0.049	1.183	1.518	0.053	2.891	4.621	19.260	0.078	8.425	1.461	33.137	0.141	10.317	2.503
03	T	0.052	2.478	4.193	0.057	3.849	4.388	19.658	0.085	6.016	1.556	33.277	0.141	7.916	2.553
04	D	---	1.750	3.384	0.044	4.926	7.238	18.427	0.079	6.069	1.470	33.995	0.146	7.702	2.586
05	D	0.039	1.535	3.042	0.034	3.666	4.305	20.853	0.090	5.920	1.737	36.505	0.158	7.648	3.257
06	D	0.043	1.373	2.116	0.049	4.031	5.937	21.473	0.089	8.196	1.561	36.318	0.149	9.532	2.526
07	D	0.036	1.387	2.288	0.045	3.404	2.868	22.157	0.093	8.394	1.753	35.262	0.153	8.182	2.764
08	T	0.036	1.585	2.645	0.045	4.398	5.304	21.570	0.090	7.271	1.874	34.923	0.150	7.844	2.755
09	T	0.044	1.479	2.218	0.048	6.267	10.103	21.976	0.092	8.259	1.698	34.582	0.149	8.934	2.688
10	T	0.040	1.470	2.446	0.064	3.139	3.786	21.295	0.091	7.421	1.783	33.594	0.134	10.211	2.381
11	T	0.036	1.278	2.116	0.047	5.071	7.651	21.278	0.092	7.894	1.739	33.958	0.144	7.750	2.542
12	T	0.026	2.648	6.980	0.046	5.193	6.639	22.498	0.095	6.623	2.055	34.061	0.147	7.088	2.536
13	T	0.047	2.497	4.192	0.056	5.489	7.438	21.206	0.086	6.318	1.637	33.241	0.141	7.770	2.613
14	D	0.046	1.391	2.298	0.042	3.629	5.287	20.789	0.086	8.709	1.669	35.561	0.154	9.658	2.714
15	D	0.041	2.035	3.174	0.050	4.577	8.657	20.089	0.087	7.452	1.592	34.367	0.147	9.011	2.560
16	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
17	T	0.035	1.862	2.719	0.057	7.064	11.948	21.643	0.092	6.713	1.801	32.194	0.137	6.790	2.526
18	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
19	D	0.040	2.029	3.706	0.055	3.847	5.277	21.491	0.092	7.920	1.729	33.839	0.143	8.627	2.569

20	D	0.043	1.619	3.416	0.045	3.528	4.086	20.834	0.086	7.002	1.732	34.049	0.145	8.276	2.790
21	D	0.021	0.929	1.415	0.051	3.042	4.172	22.848	0.098	8.976	2.008	33.114	0.142	10.017	2.484
22	T	0.044	1.388	2.270	0.055	2.798	4.061	20.833	0.087	7.741	1.582	33.390	0.143	10.286	2.615
23	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
24	D	0.020	1.438	2.100	0.043	2.772	3.519	23.117	0.099	7.736	2.005	32.966	0.144	9.525	2.459
25	D	0.044	1.888	3.012	0.042	5.476	8.829	20.801	0.086	6.869	1.647	35.110	0.150	7.965	2.628
26	D	0.049	1.866	4.579	0.043	3.398	3.994	21.302	0.087	9.323	1.588	35.447	0.152	9.019	2.518
27	D	0.024	1.341	2.188	0.056	3.457	4.928	23.284	0.100	8.926	1.970	32.916	0.141	9.049	2.509
28	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
29	T	0.039	2.030	3.044	0.043	3.608	4.374	20.479	0.089	6.112	1.537	34.118	0.145	7.898	2.536
30	T	---	---	---	---	---	---	---	---	---	---	---	---	---	---
31	D	---	---	---	---	---	---	---	---	---	---	---	---	---	---
32	D	0.039	1.540	2.409	0.053	4.789	7.449	21.979	0.093	7.353	1.637	33.578	0.142	8.903	2.423
33	D	0.024	1.775	2.684	0.051	3.256	4.065	22.727	0.099	6.736	1.999	34.947	0.145	9.748	2.696

TTS													
SUBJECT	GROUP	MLSI_PRE	APSI_PRE	VSI_PRE	DPSI_PRE	MLSI_POST	APSI_POST	VSI_POST	DPSI_POST	MLSI_RET	APSI_RET	VSI_RET	DPSI_RET
01	T	0.034	0.111	0.366	0.384	0.018	0.120	0.323	0.345	0.010	0.045	0.583	0.585
02	T	0.049	0.104	0.416	0.431	0.043	0.087	0.357	0.370	0.019	0.041	0.589	0.590
03	T	0.045	0.113	0.396	0.415	0.035	0.104	0.401	0.416	0.020	0.045	0.580	0.582
04	D	0.035	0.099	0.348	0.364	0.033	0.099	0.322	0.339	0.016	0.041	0.580	0.582
05	D	0.049	0.102	0.426	0.441	0.021	0.095	0.321	0.336	0.008	0.040	0.576	0.577
06	D	0.039	0.095	0.487	0.498	0.033	0.112	0.379	0.396	0.015	0.038	0.587	0.589
07	D	0.038	0.114	0.442	0.458	0.026	0.100	0.407	0.420	0.011	0.039	0.582	0.584
08	T	0.023	0.076	0.288	0.298	0.028	0.105	0.324	0.342	0.014	0.040	0.580	0.581

09	T	0.039	0.108	0.395	0.412	0.027	0.102	0.373	0.387	0.010	0.035	0.585	0.586
10	T	0.043	0.114	0.474	0.490	0.041	0.097	0.448	0.460	0.020	0.041	0.587	0.589
11	T	0.034	0.114	0.372	0.390	0.035	0.110	0.328	0.347	0.012	0.046	0.587	0.589
12	T	0.022	0.103	0.313	0.330	0.027	0.092	0.332	0.346	0.007	0.042	0.583	0.585
13	T	0.030	0.099	0.332	0.347	0.032	0.096	0.328	0.344	0.014	0.042	0.581	0.583
14	D	0.037	0.095	0.495	0.506	0.039	0.097	0.475	0.487	0.019	0.035	0.587	0.589
15	D	0.038	0.107	0.431	0.446	0.031	0.107	0.393	0.408	0.032	0.110	0.380	0.397
16	T	0.052	0.099	0.414	0.429	0.046	0.106	0.402	0.418	---	---	---	---
17	T	0.031	0.116	0.375	0.394	0.033	0.110	0.339	0.358	0.014	0.043	0.579	0.581
18	T	0.034	0.107	0.340	0.359	---	---	---	---	---	---	---	---
19	D	0.047	0.117	0.460	0.478	0.044	0.113	0.391	0.410				
20	D	0.026	0.113	0.352	0.371	0.034	0.103	0.348	0.364	0.013	0.039	0.582	0.584
21	D	0.041	0.098	0.374	0.390	0.045	0.105	0.344	0.363	0.017	0.042	0.589	0.591
22	T	0.027	0.099	0.342	0.358	0.021	0.097	0.318	0.333	0.013	0.037	0.582	0.583
23	T	0.042	0.100	0.412	0.426	---	---	---	---	---	---	---	---
24	D	0.040	0.114	0.369	0.388	0.036	0.096	0.326	0.342	0.012	0.038	0.583	0.585
25	D	0.031	0.095	0.357	0.371	0.030	0.101	0.284	0.303	0.010	0.040	0.579	0.580
26	D	0.039	0.131	0.517	0.535	0.039	0.110	0.442	0.457	0.016	0.040	0.580	0.582
27	D	0.037	0.100	0.406	0.420	0.045	0.110	0.431	0.447	0.019	0.041	0.583	0.585
28	T	0.039	0.086	0.430	0.440	---	---	---	---	---	---	---	---
29	T	0.030	0.111	0.313	0.334	0.028	0.097	0.311	0.327	0.014	0.041	0.580	0.582
30	T	0.032	0.101	0.307	0.325	---	---	---	---	---	---	---	---
31	D	0.026	0.103	0.322	0.339	0.024	0.091	0.306	0.320	0.014	0.043	0.581	0.582
32	D	0.052	0.115	0.445	0.463	0.042	0.121	0.435	0.454	0.017	0.046	0.586	0.588
33	D	0.039	0.096	0.385	0.399	0.039	0.098	0.369	0.384	0.013	0.039	0.581	0.583

AGILITY							
SUBJECT	GROUP	PRE_R_AVG	PRE_L_AVG	POST_R_AVG	POST_L_AVG	RET_R_AVG	RET_L_AVG
01	TRAD	9.575	9.631	9.722	9.898	9.520	9.599
02	TRAD	9.045	9.018	8.799	9.040	9.067	9.294
03	TRAD	8.677	8.705	---	---	---	---
04	DIFF	9.167	9.065	9.077	9.082	8.884	8.748
05	DIFF	9.001	8.811	9.037	9.135	9.856	10.018
06	DIFF	9.877	9.487	9.552	9.747	9.669	9.815
07	DIFF	9.256	9.146	8.643	8.859	---	---
08	TRAD	9.581	9.527	9.588	9.798	9.584	9.741
09	TRAD	8.351	8.422	8.517	8.320	9.124	9.289
10	TRAD	8.379	8.361	8.335	8.285	7.942	8.025
11	TRAD	9.204	9.144	9.193	9.835	9.314	9.522
12	TRAD	9.627	9.583	9.424	9.470	9.329	9.433
13	TRAD	8.486	8.587	8.302	8.521	8.388	8.193
14	DIFF	8.484	8.553	---	---	8.694	8.764
15	DIFF	8.140	8.068	---	---	---	---
16	TRAD	8.538	8.442	---	---	---	---
17	TRAD	9.562	9.510	9.197	9.546	9.411	9.373
18	TRAD	9.808	9.917	---	---	---	---
19	DIFF	8.377	8.442	8.235	8.719	---	---
20	DIFF	9.773	9.531	9.250	9.284	9.348	9.236
21	DIFF	9.289	9.264	9.413	9.634	8.985	9.260
22	TRAD	8.649	8.806	---	---	8.509	8.484
23	TRAD	8.713	8.571	---	---	---	---

24	DIFF	9.247	9.209	9.666	9.648	9.780	9.762
25	DIFF	9.542	9.605	9.216	9.385	9.393	9.196
26	DIFF	8.036	8.151	---	---	8.335	8.252
27	DIFF	8.765	8.843	---	---	8.713	8.996
28	TRAD	8.521	8.307	---	---	---	---
29	TRAD	9.505	9.571	9.268	9.495	---	---
30	TRAD	8.864	8.939	---	---	---	---
31	DIFF	8.496	8.555	---	---	8.724	8.933
32	DIFF	8.943	8.823	---	---	8.747	8.860
33	DIFF	---	---	9.722	9.898	---	---

APPENDIX G: ANOVA TABLES

MLTTB EO ABS MIN

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
ABSMIN*GROUP	5.546E-5	2	2.773E-5	1.007	0.372	0.037	0.216
ABS MIN	6.812E-5	2	3.406E-5	1.236	0.299	0.045	0.258
GROUP	5.048E-6	1	4.048E-6	0.066	0.800	0.003	0.57

MLTTB EO MEAN

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
MEAN*GROUP	0.162	2	0.081	0.148	0.863	0.006	0.072
MEAN	3.518	2	1.759	3.201	0.049	0.110	0.587
GROUP	2.714	1	2.714	1.112	0.301	0.041	0.174

MLTTB EO SD

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
SD*GROUP	1.730	2	0.865	0.204	0.816	0.008	0.080
SD	28.088	2	14.044	3.315	0.044	0.113	0.603
GROUP	6.916	1	6.916	0.589	0.450	0.022	0.115

APTTB EO ABS MIN

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
ABSMIN*GROUP	3.140E-5	2	1.570E-5	1.579	0.216	0.057	0.320
ABSMIN	.000	2	5.598E-5	5.628	0.006	0.178	0.839
GROUP	7.188E-5	1	7.188E-5	0.643	0.430	0.024	0.121

APTTB EO MEAN

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
MEAN*GROUP	3.900	2	1.950	0.424	0.657	0.016	0.115
MEAN	3.637	2	1.818	0.395	0.675	0.015	0.110
GROUP	0.290	1	0.290	0.023	.880	0.001	0.052

APTTB EO SD

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
SD*GROUP	11.973	2	5.987	0.178	0.837	0.007	0.076
SD	65.732	2	32.866	0.979	0.383	0.036	0.211
GROUP	13.914	1	13.914	0.314	0.580	0.012	0.084

MLTTB EC ABS MIN

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
ABSMIN*GROUP	6.224E-5	2	3.112E-5	0.930	0.402	0.039	0.201
ABSMIN	.000	2	8.686E-5	2.597	0.085	0.101	0.492
GROUP	.000	1	.000	1.300	.266	0.053	0.194

MLTTB EC MEAN

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
MEAN*GROUP	0.198	2	0.099	0.594	0.556	0.024	0.143
MEAN	2.301	2	1.151	6.920	0.002	0.224	0.908
GROUP	0.839	1	0.839	2.219	0.149	0.085	0.298

MLTTB EC SD

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
SD*GROUP	3.715	2	1.858	1.179	0.316	0.047	0.246
SD	19.006	2	9.503	6.032	0.005	0.201	08863
GROUP	0.194	1	0.194	0.055	0.816	0.002	0.056

APTTB EC ABS MIN

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
ABSMIN*GROUP	1.687E-5	2	8.4333E-5	0.295	0.746	0.012	0.094
ABSMIN	0.000	2	0.000	3.545	0.037	0.129	0.632
GROUP	0.000	1	0.000	3.455	0.075	0.126	0.430

APTTB EC MEAN

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
MEAN*GROUP	1.362	2	0.681	0.674	0.514	0.027	0.157
MEAN	0.892	2	0.446	0.442	0.646	0.018	0.118
GROUP	10.321	1	10.321	5.188	0.032	0.178	0.589

APTTB EC SD

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
SD*GROUP	7.935	2	3.968	0.842	0.437	0.034	0.186
SD	0.740	2	0.370	0.079	0.925	0.003	0.061
GROUP	7.861	1	7.861	1.069	0.311	0.043	0.168

TTS MLSI

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
MLSI*GROUP	2.174E-5	2	1.087E-5	0.378	0.687	0.015	0.108
MLSI	0.007	2	0.003	121.693	0.000	0.830	1.000
GROUP	0.000	1	0.000	2.212	0.149	0.081	0.299

TTS APSI

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
APSI*GROUP	4.525E-5	2	2.261E-5	0.214	0.808	0.008	0.082
APSI	0.066	2	0.033	310.760	0.000	0.926	1.000
GROUP	4.357E-5	1	4.357E-5	0.267	0.610	0.011	0.079

TTS VSI

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
VSI*GROUP	0.012	1.369	0.009	3.486	0.058	0.122	0.625
VSI	0.736	1.369	0.537	214.873	0.000	0.896	1.000
GROUP	0.007	1	0.007	1.790	0.193	0.067	0.251

Greenhouse-Geisser correction used

TTS DPSI

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
DPSI*GROUP	0.011	1.390	0.008	3.431	0.059	0.121	0.511
DPSI	0.639	1.390	0.460	199.954	0.000	0.889	1.000
GROUP	0.007	1	0.007	1.811	0.190	0.068	0.253

Greenhouse-Geisser correction used

AAT RIGHT

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
RIGHT*GROUP	0.002	2	0.001	0.019	0.981	0.001	0.053
RIGHT	0.079	2	0.040	0.692	0.509	0.047	0.155
GROUP	1.240	1	1.240	2.336	0.149	2.336	0.296

AAT LEFT

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
LEFT*GROUP	0.011	2	0.006	0.070	0.933	0.005	0.060
LEFT	0.142	2	0.071	0.869	0.058	1.739	0.184
GROUP	0.627	1	0.627	1.030	0.327	0.069	0.157

APPENDIX H: PEARSON CORRELATIONS

Medial/Lateral TTB

		PRE	POST	RET
EYES OPEN	*ABS MIN:MEAN*	r = -0.032 p = 0.858	r = 0.209 p = 0.276	r = 0.013 p = 0.949
	ABS MIN:SD	r = 0.042 p = 0.815	r = 0.185 p = 0.337	r = 0.053 p = 0.780
	MEAN:SD	r = 0.863 p = .000	r = 0.927 p = 0.000	r = 0.811 p = 0.000
EYES CLOSED	*ABS MIN:MEAN*	r = 0.324 p = 0.224	r = 0.427 p = 0.021	r =0.246 p = 0.226
	ABS MIN:SD	r = 0.092 p = 0.616	r = 0.163 p = 0.367	r = 0.148 p = 0.470
	MEAN:SD	r = 0.891 p < 0.001	r = 0.815 p < 0.001	r = 0.891 p < 0.001

Anterior/Posterior TTB

		PRE	POST	RET
EYES OPEN	*ABS MIN:MEAN*	r = -0.217 p = 0.224	r = -0.244 p = 0.202	r = -0.248 p = 0.204
	ABS MIN:SD	r = -0.159 p = 0.378	r = -0.344 sig = 0.076	r = -0.011 p = 0.954
	MEAN:SD	r = 0.887 p < 0.001	r = 0.810 p < 0.001	r = 0.766 p < 0.001
EYES CLOSED	*ABS MIN:MEAN*	r = -0.085 p = 0.642	r = 0.044 p = 0.822	r = 0.010 p = 0.961
	ABS MIN:SD	r = 0.102 p = 0.580	r = 0.070 p = 0.717	r = 0.083 p = 0.682
	MEAN:SD	r = 0.842 p < 0.001	r = 0.904 p < 0.001	r = 0.944 p < 0.001

	PRE	POST	RET
MLSI:APSI	r = 0.243 p = 0.172	r = 0.177 p = 0.359	r = 0.700 p < 0.001
MLSI:VSI	r = 0.679 p < 0.001	r = 0.589 p = 0.001	r = -0.670 p < 0.001
MLSI:DPSI	r = 0.686 p < 0.001	r = 0.597 p = 0.001	r = -0.664 p < 0.001
APSI:VSI	r = 0.327 p = 0.063	r = 0.291 p = 0.125	r = -0.975 p < 0.001
APSI:DPSI	r = 0.368 p = 0.035	r = 0.332 p = 0.079	r = -0.974 p < 0.001
VSI:DPSI	r = 0.458 p = 0.013	r = 0.999 p < 0.001	r = 1.000 p < 0.001