The Effects of Stable and Unstable Training Surfaces on Dynamic Postural Stability

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THE EFFECTS OF STABLE AND UNSTABLE TRAINING SURFACES ON DYNAMIC POSTURAL STABILITY

by

MARIE KIRBY

(Under the Direction of Barry Munkasy)

ABSTRACT

Context: Dynamic postural stability (DPS) is essential for skilled athletic performance, injury prevention, and rehabilitation. However, there is limited research on whether DPS training on unstable or stable surfaces elicit greater DPS improvements.

Objective: To determine whether training on stable (Wii Fit) or unstable (wobble board, WB) surfaces elicit greater DPS improvements compared to controls. Design: A three group pre-post test study. Setting: This study was performed in a controlled laboratory setting. Subjects: 29 student-athletes (24 Female and 5 males, 19.8 ± 0.89 years old, 1.72 ± 0.06 m, 71.0 ± 11.6 kg) participated in the study. Interventions: The subjects were randomly assigned to a Wii (n=9), WB (n=10), or Control group (n=10). Both the training groups participated in 12 supervised balance training sessions of 15 minutes each over four weeks. Main Outcome Measures: DPS was measured at pre and post training using the modified Star Excursion Balance Test (mSEBT, reliability .82 -.87) and the Dynamic Postural Stability Index (DPSI, Reliability .93). A change score (Post - Pre) was calculated for the mean reach length during the anterior (A-mSEBT), posterior medial (PM-mSEBT), and posterior lateral (PL-mSEBT) directions, total mSEBT scores (T-mSEBT). A change score (Post - Pre) was calculated for the mean Medial lateral stability index (MLSI), vertical stability index (VSI), anterior posterior stability index
(APSI), and dynamic postural stability index (DPSI) and compared using a one-way ANOVA with Tukey post-hoc. Subject’s enjoyment of their training protocol was reported using the Intrinsic Motivation Inventory (Reliability 0.70) and compared between Wii and WB utilizing one-way ANOVA. Results: For mSEBT significant main effects were noted for the PL-mSEBT (p=.003), A-mSEBT (p=.034), and T-mSEBT (p<.001). Post hoc testing identified both Wii and WB as outperforming control in the PL, and T-mSEBT and WB outperforming control in A-mSEBT. Overall, there were no differences between Wii and WB for any of the measures. The Wii group reported a significantly higher level of enjoyment than the WB group (P=0.007). Conclusions: Both stable and unstable surfaces improve postural stability thus suggesting both are valuable tools to improve DPSI in collegiate student-athletes; however, Wii is more enjoyable than WB.

Index Words: Balance, Balance training, Postural stability, Star Excursion Balance Test, Dynamic Postural Stability Index
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B.A., Cedarville University, 2009

A Thesis Submitted to the Graduate Faculty of Georgia Southern University in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

STATESBORO, GEORGIA

2011
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Electronic Version Approved:
May 2011
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CHAPTER 1
INTRODUCTION

Postural stability, is the ability of the body to maintain a desired orientation in response to internal or external perturbations and is typically assessed dynamically.\(^1\) Postural stability is a fundamental physical component of successful athletic participation and deficits to postural stability can cause injuries that may hinder athletic performance.\(^2,3,4,5\) However, postural stability training may help reduce the risk of injury allowing for successful athletic participation.\(^6,7,8,4,5\)

There is overwhelming evidence in the literature that postural stability training programs result in postural stability gains for healthy participants.\(^9-10\) Traditionally, balance training has been used for injury rehabilitation; however; balance training is now being used prophylactically to reduce the risk of lower extremity injuries in athletes.\(^11-14\) Research has found that in athletics knee injuries and ankle injuries are the most commonly injured site in the body.\(^6\) However, athletes who undergo postural stability training have a 20 to 60 percent lower risk of sustaining an ankle sprain than those who do not undergo balance training.\(^6\) These preventative effects have been found both for those with and without a history of previous ankle injury.\(^6\) However, athletes who have a history of previous ankle sprain have the most consistent and substantial reduction in their risk for future ankle sprains.\(^6-8\) Postural stability training has also been linked to a reduction in knee injuries by up to seven fold.\(^6\)

Exercises for postural stability improvements may include strengthening exercises and/or proprioceptive exercises performed on stable and/or unstable surfaces.\(^8-16\) Examples of strengthening exercises include 4 way ankle using a
theraband or ABC’s with a cuff weight. Stable surface exercises may include standing on one foot on a carpeted floor, or playing Wii Fit balance games. Unstable surface exercises may include balancing on a wobble board, an Airex pad, and/or a trampoline.\textsuperscript{12,17} Many of these exercises can be done with eyes open, eyes closed, and could utilize external perturbations.\textsuperscript{8-10,15-16,18} Clinicians may focus on one type of exercise or use them in combination with each other.

Although strengthening exercises and proprioception exercises have both been shown to be effective for improving postural stability, little research was found examining which training surface for proprioceptive exercises, stable or unstable, yields the greatest dynamic postural stability improvements. Most athletes perform on stable surfaces, therefore, for these athletes; stable surfaces may be the most appropriate tool for training balance. However, many stable surface exercises are easily mastered; therefore, unstable surfaces are often used after stable surfaces as a progression to make exercises more difficult. Recent developments in gaming technology have allowed stable surface exercises to become more difficult. Nintendo Wii has designed Wii Fit balance games that are performed on a stable surface and progress with increasing difficulty as a player improves. In a recent study, these balance games have been shown to improve postural stability in healthy non-athlete adults.\textsuperscript{10} However, it is still not known if the Wii Fit is challenging enough to result in the same improvements in athletes.

Although, most athletes perform on stable surfaces, the use of a wobble board as an unstable balance training tool has been shown to improve postural stability.\textsuperscript{19} A wobble board is commonly used both alone or in combination with other exercises in
postural stability training programs.\textsuperscript{20} However, it is unknown if greater postural stability improvements can be attained in athletes with training on an unstable wobble board or on a stable surface such as a Wii Fit.

With postural stability training programs a lack of interest or enjoyment in rehabilitation exercises are always a challenge. Lack of interest or enjoyment can result in a lack of motivation to improve and decreased compliance.\textsuperscript{7} However, using gaming for postural stability training has been shown to increase motivation for rehabilitation.\textsuperscript{12,14,19,21} The Intrinsic Motivation Inventory is one reliable way to evaluate motivation levels during training.\textsuperscript{22,23} Dynamic postural stability is commonly measured using the modified Star Excursion Balance Test (mSEBT), a shorter but reliable form of the SEBT, and the Dynamic Postural Stability Index (DPSI).\textsuperscript{19,24,25} The mSEBT incorporates a single-leg stance with a maximum targeted reach of the free leg in 3 directions, anterior, posteromedial, and posterolateral and has a reliability of .82 to .86.\textsuperscript{19,26} The DPSI is a biomechanical evaluation of a jump landing protocol where stability measures are taken following a landing from a jump and has a reliability for of 0.96.\textsuperscript{24}

No research was found on which training surface, stable or unstable, was more effective for training postural stability. Therefore, the purpose of this study was to determine whether training on stable or unstable surfaces elicit greater dynamic postural stability improvements when compared to control subjects as measured by mSEBT and DPSI. The secondary purpose of this study was to establish which training group would have better scores on the Interest/Enjoyment, Perceived competence, Effort/Importance, and Value/Usefulness subscales of the Intrinsic Motivation Inventory.
We hypothesized (Appendix A) that there would be a significant difference in the change in postural stability scores from pre to post testing between both training programs and the control group on the posterolateral, posteromedial, and anterior directions of the mSEBT, and on the combined total reach of the mSEBT. We hypothesized that there would be a significant difference in the change on the medial lateral stability index (MLSI), vertical stability index (VSI), anterior posterior stability index (APSI), and dynamic postural stability index (DPSI). Further, we hypothesized that there would be a difference between the change score of the stable surface group and the unstable surface group. Finally, we also hypothesized that the stable surface group’s change score would be significantly different on each subscale of the Intrinsic Motivation Inventory than the unstable surface group. For a review of the current literature pertaining to this study refer to appendix B.
CHAPTER 2

METHODS

Subjects

Thirty-three healthy varsity intercollegiate student athletes (Male n=5 Female n=28, 19.8 ± 0.89 years old, 1.72 ± 0.06 m, 71.0 ± 11.6 kg) volunteered to participate in this study. Subjects were randomly assigned to stable surface (n=12), unstable surface (n=11), or control groups (n=10) prior to data collection. Only 30 subjects completed the study and had their data analyzed due to injuries that met the exclusion criteria (stable n=9, unstable n=11, control n=10). Exclusion criteria included any injury preventing participation in normal athletic activity. The remaining 30 participants were free of injury and able to fully participate in their normal athletic activities for the entire duration of the study. Prior to the first testing session all subjects had the experiment explained to them, signed the appropriate training group or control group informed consent form to which they were assigned (Appendix C), and filled out a medical history questionnaire (Appendix D). At the first training session the mSEBT and the DPSI were explained to each subject and they were given the opportunity to ask any questions. The primary investigator enrolled all participants, conducted randomization of groups, explained each test, and conducted all baseline and follow up data collection. The primary investigator and investigative assistant shared the responsibility of supervising the training. Approval of this study was granted by the University’s institutional review board.
**Instrumentation**

Baseline and follow up dynamic postural stability testing was conducted for all 30 subjects using the mSEBT and the DPSI. All testing was performed barefoot, and order of testing was randomized using a traditional dice. The mSEBT involves 3 movements that incorporate a single-leg stance with a maximum targeted reach of the free leg (Appendix E Figure 1 and 2). The 3 movements/lines for direction of reach are anterior, posteromedial, and posterolateral according to the direction of excursion in relation to the stance leg. The stance leg was the subject’s dominate leg as defined by their preferred kicking limb. In this test the stance foot was stationary but movement about the ankle, knee, and hip occurred while the non-dominate/swing leg reached in the specified direction. The 3 directions of reach were evaluated using 3 tape measures, secured to the ground by athletic tape, with the zero point of all three tape measures meeting at the center. One tape measure was oriented directly anterior to the center and the other 2 were aligned at 135 degrees medial or lateral to the anterior direction. The ball of the subject’s foot was placed at the center of the mSEBT instrument, aligned with the tape measure facing directly anterior. The foot remained in this position for all testing. The subject was instructed to start in a double leg stance with their hands on their hips (Appendix E Figure 3). The subjects were asked to reach, while maintaining a dominate leg stance, as far as possible along the specified line with their non-dominate limb (Appendix E Figure 4-6). The subjects were instructed to lightly tap down the 1st toe of their non-dominate foot without taking their hands off their hips. The tapping foot was not to be used to provide considerable support in
maintaining upright posture. After each reach was completed the subject returned to a bilateral stance.\textsuperscript{19,25,26} The examiner marked the point the subject tapped along the line and then recorded the measure in centimeters. Trials were discarded and repeated if the examiner felt that the reach foot was used to provide considerable support when touching the ground, if the subject lifted the stance foot from the center of the grid, or if the subject lost his or her balance at any point in the trial.\textsuperscript{19,25,26} mSEBT distance was normalized to leg length, measured in centimeters from their Anterior Superior Iliac Spine to the distal tip of their medial malleolus, by dividing the reach score by limb length, then multiplying by 100.\textsuperscript{19} Four practice trials and 3 test trials were performed for each direction.\textsuperscript{19} The order of direction of reach was randomized for each subject.\textsuperscript{19} The mean of the 3 trials was calculated for each direction of reach and normalized yielding a separate score for the anterior, posteromedial, and posterolateral directions.\textsuperscript{19} The mSEBT is valid and has a reliability of ranging from 0.82 to 0.86.\textsuperscript{26}

For the DPSI all measures were taken on the dominate limb as previously defined. The subjects started in a bilateral standing position 70 cm from the center of a force plate (Appendix E Figure 7).\textsuperscript{19,24} The subject jumped over a 23 cm hurdle with both legs and landed solely on their dominate limb on a force plate, stabilized as quickly as possible, put their hands-on their hips when they felt stable, and balanced for 10 s with hands on their hips, looking straight ahead (Appendix E Figure 8).\textsuperscript{19} The reliability of this jump protocol is 0.84. Subjects were given a marker straight ahead to focus on and instructed to jump with their head up. Before performing the actual protocol subjects were taken through a jump progression. First they were instructed to pretend a 23 cm hurdle was in front of them and to “jump over it” and land in the center of the force plate
on both legs, then to perform the same task and land on only their dominate leg. The hurdle was then placed along the jump path and they were instructed to jump over it and land on only their dominate leg. Subjects were allowed as many practice trials as needed to feel comfortable with the jump protocol with a 2-minute rest period between practice and testing to reduce potential fatigue affects. Following their rest period 3 test trails were performed. If a subject lost their balance and touched the floor with the non-dominate limb, if a short additional hop occurred on landing, or if excessive swaying of the non-dominate limb, arms, or trunk occurred, the trial was discarded and repeated. Excessive swaying was defined as enough sway that the subject all but stepped off the force plate.

Nexus software (Vicon Version 1.5.2, Centennial, CO) and a strain gauge non-conducting embedded force plate (Advanced Medical Technology Model OR-6, Inc., Watertown, MA) was used to collect the baseline and post training jump-landing ground reaction force data (1000 Hz). The data underwent an analog-to-digital conversion and was stored on a laboratory computer.

The DPSI was calculated as described by Wikstrom. The three directional components of the ground reaction force in Newton’s, for the first 3 s following ground impact, was read into Excel and the DPSI, MLSI, VSI, and APSI was calculated using the formula $DPSI= \sqrt{[(\sum(0-x)^2 + \sum(0-y)^2 + \sum(1-z)^2)/\text{number of data points}]}, \quad MLSI = \sqrt{\sum(0-x)^2)/\text{number of data points}}, \quad VSI = \sqrt{\sum(1-z)^2/\text{number of data points}}, \quad APSI = \sqrt{\sum(0-y)^2/\text{number of data points}}$. For all formulas $x$, $y$, and $z$ are the anterior/posterior forces divided by body weight, medial/lateral forces divided by body weight, and vertical
ground reaction forces divided by body weight, respectively. The reliability of the formulas are high (ICC = 0.96).

On the post test day those who participated in the training protocol were asked to fill out an Intrinsic Motivation Inventory (IMI) (Appendix F). Subjects were informed that all answers were confidential and asked to answer as honestly and accurately as possible. As instructed by the directions given for the Intrinsic Motivation Inventory, 4 subscales (Interest/Enjoyment, Perceived competence, Effort/Importance, and Value/Usefulness) most pertinent to answering our theoretical questions were chosen. The order of these questions was randomized. For the “value/usefulness items”, we complete the three items as appropriate to our study (Appendix D). The version of the Intrinsic Motivation Inventory used in this study consisted of 25 questions scored on a Likert scale from strongly disagree (1) to strongly agree (7). Negatively worded items were rescaled as directed in the Intrinsic Motivation Inventory directions. Then, the subscale scores were calculated by averaging across all of the items on that subscale. The IMI has a reliability of 0.70 and a validity of 0.85.

**Training protocol**

Following pre testing of the mSEBT and the DPSI the training group subjects completed 12 training sessions of 15 min on either a stable surface (Wii Fit) or an unstable surface (Wobble Board). These 12 sessions were conducted at least 24 hours apart and no more than 3 sessions were conducted each week. For each 15 minute session the stable surface group performed 5 minutes each on three different Wii Fit Plus (Nintendo, CO) balance games (Table Tilt, Tilt City, and Ski Jump). How to play each game and the goal of each game was briefly described to the subject before their
first training session. For each 15 minute session the unstable surface group performed 5 minutes of anterior/posterior tilts, 5 minutes of left/right tilts, and 5 minutes of circular rotation (2.5 minutes in each direction). Both groups of subjects were instructed that they were not being judged on how well they performed the task just that they performed it for the specified period of time. All training was done barefoot and in a bilateral stance.

**Analysis**

Statistical significance was set at p<.05. The dependent variables were the change scores on the mSEBT and the DPSI and the independent variables were the stable surface training group, the unstable surface training group, and the control group. Data were analyzed using IBM SPSS standard version 17 (IBM, CO). One way ANOVAs with repeated measures were used to compare all directions of mSEBT and all components of the DPSI change scores (post test score – pre test score) between the three groups (Stable, Unstable, Control). One way ANOVAs were used to compare difference in scores for the Intrinsic Motivation Inventory between the two testing groups (Stable, Unstable).
CHAPTER 3

RESULTS

Out of 33 subjects enrolled in the study 30 subjects fully completed the study. Those who did not complete the study were excluded during training or prior to post testing due to an injury they obtain at their sport practices. No injuries occurred during training or testing.

Modified Star Excursion Balance Test

For mSEBT a significant difference was found between groups (stable, unstable, control) for the posterolateral reach (F= 7.2) (mean control = -4.5 ± 5.8, stable = 7.8 ± 6.7, unstable = 6.5 ± 10.3) (Appendix E, Figure 9). Tukey's post hoc test demonstrated statistically significant improvement in the posterolateral reach distance in both the stable group (p=.006) and the unstable group (p=.011) from baseline to follow up when compared to the control group (ES cont/wb = 1.89655, cont/wii = 2.12069). There was no significant difference for reach distance between the stable and unstable groups (p=.932) (Power wb/wii = 0.15). No significant difference between groups was found for the posteromedial reach (F= 2.9) (mean control = .5 ± 7, stable = 8.2 ± 4.9, unstable = 5.2 ± 8.6) (Appendix E, figure 10) (Power cont/wb = 0.99, cont/wii = 0.42, wb/wii = 0.42). However, exploratory analysis did show a trend toward improvements in posteromedial reach distance for the stable surface group (p=.062). A significant difference between groups was found for the anterior reach (F= 3.8) (mean control = 1.7 ± 3.1, stable = 5.5 ± 6.2, unstable = 6.7 ± 2.6) (Appendix E, figure 11). Tukey's post hoc test demonstrated a statistically significant increase in the anterior reach distance in the unstable surface group compared to the control group (p=.034) (ES cont/wb = -1.6129). There was no significant difference found between the stable surface group and the
control group (p=.14) (Power = .99) or between the stable surface group and the unstable surface group (p=.807) (Power = 0.37). A significant difference between groups was found for the total reach distance (F= 10.6) (mean control = -2.3 ± 10.5, stable = 21.6 ± 11.9, unstable = 18.5 ± 14.6) (Appendix E, figure 12). Tukey's post hoc test demonstrated a statistically significant increase in reach distance for both the stable surface group (p=.001) and the unstable surface group (p=.003) when compared to the control (ES control/stable = -1.8381 control/unstable =1.54286). There was no significant difference between the improvements in reach distance between the stable and unstable surface groups (p=.851) (Power unstable/stable = 0.23).

*Dynamic Postural Stability Index*

For DPSI a one way ANOVA revealed no significant difference between groups for DPSI (p=.747) (Power cont/wb = 0.33, cont/wii = 0.33, wb/wii = 0.05), VSI (p=.837) (Power cont/wb = 0.171, cont/wii = 0.24, wb/wii = 0.06), APSI (p=.282) (Power cont/wb = 0.66, cont/wii = 0.66, wb/wii = 0.66), or MLSI (p=.504) (Power cont/wb = 0.46, cont/wii = 0.7, wb/wii = 0.1) (Appendix E, figure 13-16).

One subject was excluded from the analysis because her reach distance on the mSEBT decreased more than double any other decrease found for any other subject. Upon further investigation it was noted that the subject wore athletic shorts to her pretesting and jeans to her post testing which may have skewed her results.

*Intrinsic Motivation Inventory*

A significant difference between groups was found for the Interest/Enjoyment subscale (F= 9.4) (Appendix E, figure 17). Subjects in the stable surface group (5.04 ±
1.18) were more interested and enjoyed their training significantly more than those in the unstable surface group (3.17 ± 1.31).

No significant difference between groups was found for the perceived competence subscale (F= .27) (mean stable = 5.5 ± .6, unstable = 5.3 ± .8) (Power =0.13) (Appendix E, figure 18). No significant difference between groups was found for the effort and importance subscale (F= .06) (mean stable = 4.7 ± 1.1, unstable = 4.9 ± 1) (Power =0.07) (Appendix E, figure 19). No significant difference between groups was found for the value and usefulness subscale (F= .6) (mean stable = 4.8 ± 1.3, unstable = 5.3 ± 1.3) (Power =0.13) (Appendix E, figure 20).
CHAPTER 4

Discussion

The results of this study showed significant improvements in mSEBT reach distance for the posterolateral direction and total reach distance when utilizing both stable and unstable surfaces for postural stability training compared to controls. Significant improvements in reach distance were also found for the unstable surface training group in the anterior direction when compared to the control group. No significant differences in amount of improvement from pretesting to post testing were found between the stable and unstable groups for any direction of reach. No significant difference between groups was found for the DPSI or any component of the DPSI. Subjects in the stable surface group were more interested and enjoyed their training significantly more than those in the unstable surface group. No significance was found for the perceived competence, effort and importance, or value and usefulness subscales.

Results from this study are similar to a study by Fitzgerald where subjects performed 4 weeks of wobble board training and were pre and post tested using both the mSEBT and the DPSI. If change scores are calculated for their wobble board group they increased their reach by 2.4 cm in the anterior direction, 6.4 cm in the posteromedial direction, 10.7 cm in the posterolateral direction, and 1.1 on the DPSI. These results are similar to the improvements seen in the unstable (wobble board) group in our study for the mSEBT(anterior reach 6.74 ± 2.61, posterior medial reach 5.21 ± 8.61, posterior lateral reach 6.52 ± 10.27). Our dynamic postural stability index results are different (-.01 ± .02) but the formula he used was not the most current
version of the formula, therefore, our formulas were different. Hale reports baseline scores in healthy subjects of 71 ± 10cm in the anterior direction, 84 ± 11cm in the posteromedial direction, and 77 ± 13cm the posterolateral direction. These scores are similar to the baseline scores obtained in this study (anterior 79.85 cm, posterior medial 97.69 cm, posterior lateral 89.79 cm). There was no research found that assessed total mSEBT values. Wikstrom took MLSI, APSI, and VSI values when creating the DPSI as a valid measure of postural stability. His original research measures for the first 3s of landing were MLSI 0.22, APSI 0.38, VSI 0.62, and DPSI 0.77. The baseline scores in our study are lower than Wikstroms (MLSI 0.03, APSI 0.11, VSI 0.30, and DPSI 0.32) because we used a slightly different and more current formula.24 Our numbers are however, very similar to a recently published Wikstrom article where we used the same version of the formula. He reported a MLSI of 0.03, APSI of 0.13, VSI of 0.17, and a DPSI of 0.22, however, he only collected data for the first 1 s of landing and we collected for 3 s as he recommended for athletic activities, this may explain the slight different in the VSI values.27

Unexpectedly improvements were similar between the stable and unstable surface training groups. It was hypothesized that there would be a difference between the stable and unstable groups because athletes perform on stable surfaces and the testing surface was stable. One possible reason there were similar improvements in reach distance for both the stable and unstable surface training groups may be that both the stable and unstable groups actually performed similar movements when training, resulting in similar adaptations.20 For the Wii Fit Ski Slope game, used as one of the stable surface exercises, the subject is constantly dorsi and plantar flexing their ankles.
In order to ski down the slope the subject leans forward, dorsi flexing their ankles, and in order to make their video character jump off the slope they plantar flexing their ankles and extend their phalanges. This is similar to what happened at the ankle with the wobble board, which was used as the unstable surface tool. The subject rocks the wobble board forward and backward. With the rock forward their ankles move into dorsi flexion, and as they rock backward their ankles go into plantar flexion. For the Wii Fit Tilt City game the subject continually shifted their bodyweight right and left in order to accomplish the goal of the game. The wobble board subjects also shifted their weight right and left to tilt the wobble board which results in similar motions at the ankle. For the Table Tilt game subjects rotated their body in all different directions. The wobble board subjects performed rotations in both directions creating a similar movement in the ankle to the movements that occur in the Tilt City game. Therefore, similar improvements on the postural stability measures may be due to the similar movements that occur at the ankle in both the Wii Fit games and the wobble board exercise.

It is possible that time on task affected the results of this study. Both the stable surface and unstable surface groups trained on their training tools for 15 minutes per session. However, the Wii Fit groups was not actually performing a postural stability training task the entire 15 minute duration. The games used for the stable surface had to reset each time the task was completed resulting in only approximately 12 minutes of actual time on task, whereas, the wobble board group was performing their exercises continuously for the entire 15 minutes. Had the stable surface group spent the same amount of time on task as the unstable surface group, differences between the stable and unstable group’s improvements in postural stability may have been found. Future
research using these exercises may want to increase the total time of the Wii Fit training in order to account for the reloading between attempts on the Wii Fit games.

The similar improvements in reach distance for both the stable and unstable surface training groups suggests that when using a stable surface or unstable surface to train postural stability, postural stability will improve to a similar level. The lack of DPSI improvement may be because postural stability training on the ground improves only postural stability while at least one foot is in contact with the ground and not the ability to stabilize after landing from a jump. The training program did not involve jumping or landing tasks. Future research could address using the DPSI to evaluate postural stability training programs that include jumping and landing tasks.

The training groups may have improved compared to the control because of neural adaptations that occur with balance training. For many years it was assumed this adaptation occurred peripherally, however, recent research suggests there may also be central nervous system changes and/or changes in the brain.

Previous research studies have shown that postural stability training programs result in postural stability gains for both healthy and injured participants. Postural stability training programs are commonly used for injury rehabilitation and to reduce the risk of lower extremity injuries in athletes. Because both improve postural stability as shown by improved mSEBT scores, a Wii Fit and wobble board both are effective tools that should be considered when developing postural stability programs.

An Intrinsic Motivation Inventory was also used for this study. Based on this inventory a Wii Fit system was found to be more interesting and enjoyable for subjects when training postural stability. This increased interest and enjoyment may be due to
the fact that it is a game that has a clear goal that is challenging but attainable. Using the Wii Fit the subject can see their success by how far they jump in the Ski Slope game, how far they progress through in the Table Tilt game, or how many points they earn in the Tilt City game, whereas, the wobble board group completed a repetitive cycle of motions without any visual mark or feedback of success. This increased interest and enjoyment is consistent with other literature that shows gaming for balance training increases motivation and enjoyment in rehabilitation.\textsuperscript{26,17} Due to this increased enjoyment and similar postural stability improvements a Wii Fit may be a better choice for postural stability training so as to both improve balance but keep patients interested and enjoying what they are doing.

This study found that both the groups training on the stable and unstable surface had the same perceived competence, gave the same effort, allotted the same importance to the training, viewed the training to the same degree of usefulness, and saw the training as equally valuable and useful to them. This may be because both groups where explained the potential benefits to postural stability training when being recruited as a means for recruitment so they went into the study with a preconceived value to the study and a possible bias resulting in equal effort.

Another observation from this study is that double leg postural stability training does improve single leg postural stability. Both training programs involved both feet being on the ground for the entire training session, whereas the mSEBT assessed single leg postural stability. This may have occurred because both extremities are being challenged so both are making improvements both as a single unit and together.
Future research should explore if single leg training improves postural stability more than double leg postural stability.

**Limitations**

Limitations of this study include small sample size. For most of results that were not significant the power was low due to small effect sizes. Future research should be done to see if increasing the sample size would find additional significant results. Limitations also include not being able to control for noise while athletes were training and testing. As shown by Onate, distractions can affect balance.\(^2\) To minimize the effects of noise we had the athlete’s pre test and post test in a laboratory setting at the same time of day so that similar noise would be present.\(^2\) Both in and out of season sports were used. Sport team training often includes agility type exercises as well as weight programs in addition to their skills practices. Hess found that in four weeks of agility training performed by college age individuals with one structurally unstable ankle there were no improvements in postural stability.\(^2\) However, Kibele found that seven weeks of strength training improves static and dynamic balance.\(^3\) Therefore, it is possible that the team strength training the subjects did in or out of their sport season may have been affected changes to postural stability. However, groups were randomized and a control group was used. Although subjects were asked some injury questions in their pre screening the only exclusion criteria was a current injury that affects their sport participation. Past injury history such as repetitive ankle sprains were not accounted for. Our study had many subjects who had a history of injuries, however, the groups were randomized so it should not affect the results. It should also be noted the primary investigator personally knew some of the athletes. This may have aided in
their recruitment and the effort they gave during training and testing, however, this should be random across groups so it should not have an effect on the overall results. Collegiate athletes were specifically chosen, therefore, the generalizeability of the results should be interpreted with caution and further research should be conducted to examine if results can be applied to different age and subject populations. We did not evaluate or control for previous experience with either Wii Fit or wobble board training. Future research should be conducted to see if previous experience with the training tool effects rate of improvement in postural stability when training with that tool. Also, we asked subjects to not do any additional postural stability training outside of their normal team practice sessions, however, with the wide availability of Wii Fit and other balance training tools we cannot be sure they did not train in addition to their set 12 sessions.

Further research is required to examine combinations of stable and unstable surface training and/or jump training to determine what combination of training is most effective to improve all areas of postural stability as well as to determine the best way to improve double and single leg postural stability.

**Conclusions**

Postural stability training exercises on a stable surface and unstable surface improve postural stability equally when compared to controls. However, subjects were more interested in and enjoyed the stable (Wii Fit) training to a greater extent as compared to unstable (wobble board) training. As clinicians both of these tools could be utilized to improve an athlete’s postural stability; however, the Wii Fit balance games may be a unique enjoyable way to get your athlete training postural stability often.
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APPENDIX A

RESEARCH HYPOTHESES

H\textsubscript{A1}: For the average change in mSEBT average anterior reach, the stable group will improve more than the unstable group and both the stable and unstable groups will improve more than the control group.

H\textsubscript{A2}: For the average change in mSEBT average posterior medial reach, the stable group will improve more than the unstable group and both the stable and unstable groups will improve more than the control group.

H\textsubscript{A3}: For the average change in mSEBT average posterior lateral reach, the stable group will improve more than the unstable group and both the stable and unstable groups will improve more than the control group.

H\textsubscript{A4}: For the average change in mSEBT total reach, the stable group will improve more than the unstable group and both the stable and unstable groups will improve more than the control group.

H\textsubscript{A5}: For the average change in DPSI, and each component of DPSI (MLSI, APSI, VSI), the stable group will improve more than the unstable group and both the stable and unstable groups will improve more than the control group.

Limitations

• Unable to control noise while training.

• Past injury history such as repetitive ankle sprains were not accounted for.

• Groups were made up of both in and out of season sports.

• The primary investigator personally knew some of the athletes.
• We did not evaluate or control for previous experience with either Wii Fit or wobble board training.

**Delimitations**

• Only collegiate athletes were used.

• Only athletes 18 years of age or older were recruited.

• Pre and post testing was performed on a stable surface only.

**Assumptions**

• The subjects will be truthful on their injury history questionnaire.

• Subjects are giving maximal effort at all times during the testing.

• Subjects are not performing any outside postural stability training.
APPENDIX B

REVIEW OF LITERATURE

Balance Defined

Balance is a term used by health care providers on a regular basis, but what exactly is balance? Some researchers suggest health care providers have an intuitive understanding of the term balance, although it is difficult to specifically define.\(^{19}\) Hrysomallis defines postural balance as, “the ability to achieve a state of equilibrium by maintaining the body’s center of gravity over the body’s base of support.”\(^{12}\) When trying to define balance, there are many terms used, some of which are used interchangeably in the literature. These terms need to be discussed and defined. The terms include; equilibrium, center of mass, center of gravity, center of pressure, stability, postural stability, postural control, and proprioception.

The term equilibrium is derived from Newtonian mechanics.\(^{2}\) Equilibrium can be either static or dynamic. Static equilibrium is the ability of an object to be at rest; whereas, dynamic equilibrium is the condition where an object is in constant motion.\(^{2}\) In the literature balance, at times, has been used synonymously with equilibrium.\(^{2}\) However, balance is equilibrium around a certain axis.\(^{2}\)

The terms center of mass and center of gravity are often used interchangeably. Center of mass of the body is a point about which the body’s mass is equally distributed in three dimensional space.\(^{20,21}\) Center of gravity is the point of origin of the weight vector, which is where all particles of the body are evenly distributed.\(^{20,21}\) Center of gravity differs from center of mass in that center of gravity refers only to the vertical direction because it is the direction in which gravity acts.\(^{20,21}\) Center of pressure is “the
location of the vertical ground reaction force vector from a single force platform, assuming that all body contact parts are on that platform."

In a static position an object’s ability to balance is a function of the relative position of its center of mass and its base of support. The object is considered balanced if its center of mass falls within its base of support. As the object’s center of mass shifts outside the base of support it becomes unbalanced.

Stability is the ability to remain in, or return to, a state of balance. Something that is balanced is considered stable; something that is unbalanced is considered unstable. Therefore, the more displacement of the line of gravity allowed before the center of mass falls outside of the base of support, the more stable the object. The more force that can be applied before an object becomes unbalanced the more stable the object.

There are both external and internal forces that act on a body that challenge stability. External forces are forces outside of the body itself, for example, ground reaction force, friction, air resistance, and gravity. Internal forces are forces that act within the body like muscle contractions and reaction between the Central Nervous System (CNS).

Postural stability is the ability to maintain postural orientation despite forces applied, whether external or internal. Postural stability must be maintained during both static and dynamic states. Dynamic postural stability is more challenging because it requires the ability to maintain balance while accelerating and/or transitioning from a dynamic to a static or static to dynamic state. Postural steadiness is the ability to remain as motionless as possible. Some mechanical variables that can affect postural
stability include base of support width, center of mass height, and center of mass centrality within the base of support.

When discussing postural stability the term postural control is often used. In a human, center of gravity is high, and base of support is small, which makes stability more difficult. However, humans have the ability, when their center of mass falls outside their base of support, to correct the problem in order to maintain balance and not fall. Therefore, humans have control over balance. This ability to sense threats to balance and correct the problem, in order to remain stable, is called postural control. Postural control involves maintaining stability and body orientation in space. Postural control is the ability to maintain a specific posture, move between postures, and/or react to external disturbances. Postural control can be obtained through either reactive forces or predictive forces. The body can have an external force applied to it causing center of pressure to shift, resulting in a reaction by the body to shift in order to maintain or regain balance; or, the body can predict there will be a threat to stability and move, or activate muscles to help combat the force, so that they never become unbalanced.

Proprioception is also used in association with the term balance and is key to balance training. Proprioception refers to the sensation of joint movement and the ability to sense joint position. Proprioception is a component of the somatosensory system. Proprioception is needed to predict or react to threats to balance so as to remain stable. “Proprioceptive sense is derived from a cumulating of sensory input from specialized receptors in muscles, joint capsules, ligaments, and cutaneous receptors that is conveyed to the central nervous system through afferent neural
There are many factors that contribute to balance, proprioception, is only one of these components.

**Factors Contributing to Balance**

Balance is obtained through sensory input which is received and processed by the brain and spinal cord. The ability to maintain balance through preventative or correcting actions comes from various sensory inputs into the central nervous system including visual, vestibular, and somatosensory components. The somatosensory system “functions to detect sensory stimuli such as touch, pain, pressure, and movements such as joint displacement.” The somatosensory system receives input from the peripheral articular and musculotendinous receptors signaling changes in muscle length and tension, and information regarding joint position and motion. The vestibular system receives information from the ear’s vestibules and semicircular canals when head position changes contributing to the perception of body position for special awareness aiding in the maintenance of body posture. This information can be used to control eye musculature so as to maintain visual focus when the head changes position, to maintain upright posture, and/or for conscious awareness of body and joint position, and motion. The visual system provides the CNS with information to maintain balance through visual cues used as reference points to orient the body in space. Through visual feedback the supraspinal mechanisms can accurately modify spatial orientation of the body to adapt postural behaviors and movement. The somatosensory and visual inputs are the primary contributors to balance and postural awareness.
Sensory inputs into the central nervous system are sent by way of the neural-feedback loop between the CNS and the musculoskeletal system.\textsuperscript{18,27} A feed-forward mechanism of cognitive control initiates preventative movements that help maintain balance in anticipation of disturbances.\textsuperscript{18,27} Both feed-forward and feedback controls come from information gained from previous motor experiences.\textsuperscript{18,27} Therefore, experience plays a role in being able to anticipate disturbances and proprioception is key for maintaining balance through neuromuscular control.\textsuperscript{18}

Neurological and musculoskeletal injuries or conditions are two factors that contribute to balance deficits.\textsuperscript{28} Research shows that ankle injuries cause a decrease in balance ability.\textsuperscript{11,16} A study done by Bahar showed risk of recurrent injury is largely increased in the first twelve months following injury most likely due to stability deficit. However, Bahar also found you can reduce your risk of re injury if balance training programs are performed during the first year following injury.\textsuperscript{16} It may also be beneficial to continue long term balance training because Bahar’s study also showed that balance training injury reduction rate continues to increase over time for up to two years.\textsuperscript{16}

Balance is important for daily life and is especially important for athletes due to the nature of sports. In fact, Gambetta went as far as to say balance may be “the single most important component of athletic ability.”\textsuperscript{1} Sports demand good balance and control from athletes, therefore, balance problems, even mild ones, may affect an athlete’s performance.\textsuperscript{1}

**Star Excursion Balance Test**

In order to quantify balance so as to identify balance deficits and/or show changes in balance, various balance assessment tools have been developed. The Star
Excursion Balance Test (SEBT) was created in order to provide non instrumented dynamic balance protocols that effectively challenge the postural control systems of well-conditioned, physically active individuals.29

The SEBTs is a series of 8 unilateral balance tests that incorporate a single-leg stance with a maximum targeted reach of the free leg.15,29 As the targeted reach is performed with the foot, the subject’s postural stability is challenged as the body’s center of mass is moved in relation to its base of support. Good postural stability and control is crucial to increasing the length of excursion of the reach leg. The SEBTs is performed with the subject standing at the center of a grid laid on the floor with 8 lines extending at 45’ increments from the center of the grid. The 8 movements/lines for direction of reach are anterior, anteriomedial, anterolateral, lateral, medial, posterior, posteromedial, and posterolateral according to the direction of excursion in relation to the stance leg. The stance leg is the subject’s dominate leg as defined by their preferred kicking limb. In this test the dominate/stance foot is stationary but movement about the ankle, knee, and hip occurs while the non-dominant/swing leg reaches in the specified direction. The subject is instructed to maintain a dominate leg stance while reaching to tap with the non-dominant leg as far as possible along the specified line with the most distal part of their non-dominant foot. The tapping foot is not to be used to provide considerable support in maintaining upright posture. After each reach the subject returns to a bilateral stance. The examiner marks the point the subject tapped along the line and then measure the distance from the center of the grid to the tap point with a tape measure. Typically, trials are discarded and repeated if the examiner feels that the reach foot was used to provide considerable support when touching the ground,
if the subject lifts the stance foot from the center of the grid, or if the subject loses his or her balance at any point in the trial.\textsuperscript{15,29} The intratester reliability for examiner range from .78 to .96 and the intertester reliability range from .81 to .93.\textsuperscript{29}

The modified star excursion balance test was created in order to cut testing time and has been shown to be equally reliable.\textsuperscript{17} The mSEBT involves 3 movements, rather than 8. The 3 movements/lines for direction of reach are anterior, posteromedial, and posterolateral according to the direction of excursion in relation to the stance leg. The reliability of the modified SEBT ranges from .82 to .86.\textsuperscript{24,30}

Because leg length effects the reach distance when using the SEBT the reach distance should be normalized to leg length by dividing the maximum reach score by limb length, then multiplying by 100, to give the reach distance as a percentage of limb length.\textsuperscript{31} The reliability of normalizing for leg length is .99.\textsuperscript{32}

**Dynamic Postural Stability Index**

The Dynamic Postural Stability Index (DPSI) is another measure of postural stability. It was developed in order to closely mimic athletic activity in order to get an accurate measure of postural stability that would be relevant to an active population.\textsuperscript{22} This measure is based on previous assessments of single-leg stance and single leg hop stabilization tests with the underlying premise that dynamic postural stability depends on lower extremity kinematics at landing as well as on muscular activation patterns and eccentric control.\textsuperscript{22} For the DPSI, all measures are taken on the dominate limb as defined by the kicking leg. The subject starts in a bilateral standing position 70 cm from the center of a force plate. The subject jumps with both legs and touches an overhead marker, which is placed at a height of 50% maximum vertical leap, with a single arm of
his or her choosing before landing on the force plate. Each subject lands on the stance leg, stabilizes as quickly as possible, and balances for 10 seconds with hands on the hips, looking straight ahead. All subjects are instructed to jump with their heads up and hands in a position to touch the designated marker and then to place their hands on their hips as soon as they feel stable. A force plate is used to collect baseline and jump-landing GRF data. The force-plate data undergoes an analog-to-digital conversion and is stored on a computer. The GRF is low-pass filtered with a frequency of 1000 Hz and a gain setting of 1. The reliability of the DPSI ranges from .917 to .99.

In order to save testing time by not having to determine 50% jump max, Fitzgerald made modified the jump protocol. For the modified protocol, the subject jumped over a 23cm hurdle with both legs and landed solely on their dominate limb on a force plate, stabilized as quickly as possible, and balanced for 3 seconds with hands on their hips, looking straight ahead. If a subject loses balance and touches the floor with the non-dominant limb, the trial is discarded and repeated. If a short additional hop occurs on landing or if excessive swaying of the non-dominant limb, arms, or trunk occur, the trial should be discarded and repeated. Excessive swaying is operationally be defined as enough sway that the subject all but stepped off the force plate. The reliability for the modified jump protocol was .84.

Data is taken from the three directional components of the ground reaction force in Newton’s, for the first 3 seconds following ground impact, and the DPSI for each jump is calculated using the following formula: 

\[ \text{DPSI} = \sqrt{ \sum (0-x)^2 + \sum (0-y)^2 + \sum (\text{body weight} - z)^2} \]
number of data points where x, y, and z are the anterior/posterior, medial/lateral, and vertical ground reaction forces, respectively.\textsuperscript{15,22}

**Balance Training: Healthy Subjects**

Postural control is highly adaptable and can be improved with balance training.\textsuperscript{47} There is overwhelming evidence in the literature that balance training programs result in balance gains for healthy participants.\textsuperscript{7,23,11,15, 33-34} These improvements have been found specifically in college age athletes\textsuperscript{35, 10, 9} Most of these studies were conducted using traditional balance training methods, however, Brumels noted balance gains in college age non athletes, from pre training to post training, when Dance Dance Revolution and Wii Fit balance games were used, as well as, balance gains in the traditional training group when performed 3 times a week for 12 minutes over the course of four weeks.\textsuperscript{8}

There is some evidence that suggests that balance does not significantly improve with training.\textsuperscript{7,36} Conflicting findings may be a result of poor methodology, randomization, or the balance training program used.\textsuperscript{7} Blackburn and Emory are both of particular interest because they look at both static and dynamic balance gains.\textsuperscript{7,9} Static balance was assessed using the NeuroCom Smart Balance Master long-forceplate system, semi-dynamic balance was measured using the Biodex Stability System, and dynamic balance was assessed using the Bass Test of Dynamic Balance. Although Blackburn found significant balance improvements in semidynamic balance and dynamic balance in college age subjects, he found no balance improvements in static balance after the six week balance training program when comparing pre and post measures.\textsuperscript{7} Contrary to Blackburn’s findings, Emory did a study testing both dynamic
and static balance in one hundred and twenty seven, high school age, subjects and found improvements in both dynamic balance and static balance, while the control group remained the same after a six week training program.\textsuperscript{7, 9} These differences in finding could be due to the differences in training programs. Blackburns program appears to be heavily geared toward smeidynamic and dynamic type exercises whereas Emory’s program has a mix of both static and dynamic.\textsuperscript{7, 9} Although there is conflicting evidence there appears to be a more substantial amount of accurate evidence that balance training improves balance.

**Balance Training and Injury Risk**

Injuries occur when force is applied greater than the structure can withstand.\textsuperscript{12} In order to prevent injury, the structure either needs to be able to handle a greater load or the force applied needs to be less.\textsuperscript{12} According to Hrysomallis, balance training may promote “neuromuscular mechanisms responsible for the co-contraction of agonist-antagonist muscles that enhance active joint stability.”\textsuperscript{12} This co-contraction of agonist and antagonist muscles leads to tighter joints, resulting in greater joint stability, which then leads to the ability to handle stresses placed on the structures and, therefore, less injury.\textsuperscript{12}

Traditionally, balance training has been used for injury rehabilitation, however, balance training is successfully being used more and more to prevent ankle and knee injuries in athletes.\textsuperscript{12, 11, 15, 9, 34, 37} Balance training improves the regeneration of neuromuscular structures resulting in prevention of injury-recurrence.\textsuperscript{47} According to McKeon, in his analysis of three studies, athletes who undergo balance and coordination training have a 20-60% lower risk of sustaining an ankle sprain than those
who did not undergo balance training.\textsuperscript{11} Hertel and Verhagen both found that athletes who had a history of previous ankle sprain had the most consistent and significant reduction in their chances for future ankle sprains.\textsuperscript{5,6} McKeon also found preventative effect for those with a history of previous ankle sprain.\textsuperscript{11} These findings are constant with other research that found a reduced rate in recurrent ankle sprains in soccer players, recreational athletes and volleyball players.\textsuperscript{6}

According to the Grindstaff's study, balance and coordination training results in a 70\% lower risk of anterior cruciate ligament tears.\textsuperscript{38} Another study by Caraffa showed that balance training reduced the rate of knee injury by seven fold in a sample of male soccer players.\textsuperscript{39} Malliou, also showed balance significantly reduced lower extremity injuries.\textsuperscript{10}

Bahr, in his study comparing one year of balance training and two years of balance training, found that athletes in their first year of balance training had a twenty-one percent reduction in rate of injury, whereas, athletes who were in their second year participating in balance training, had a sixty percent reduction in rate of injury.\textsuperscript{16} This may suggest that balance training has a cumulative effect. The longer you perform balance training the more benefits gained toward injury reduction.\textsuperscript{16}

According to McKeon's review of literature, evidence is inconclusive concerning reduction in injury rates in athletes with no history of previous ankle sprains.\textsuperscript{11} McKeon suggests that the reason there is a higher injury reduction rate in those with previous ankle injuries may be because they are predisposed to recurrent injury so it takes a lower volume of balance training to see positive effects.\textsuperscript{11} Those with no previous history have a greater postural stability therefore a low risk or injury so it may take a
higher volume and longer term balance training to obtain significant injury reduction rates.  

When athletes are categorized first by balance ability, and then injury risk is calculated based on number of the injuries, findings can be controversial. A study by Tropp showed that soccer players categorized with poor balance compared to teammates had four times the number of ankle injuries than those with normal balance. 11 Tropp had no rational for his reference number that quantified the “poor balance” group. 11

Ankle injuries and balance ability were shown to be related in a study using 210 subjects, by McGuine, in youth basketball players. 44 The NeroCom balance system was used to assess balance for this study. Subjects were grouped into a poor balance group, a normal balance group, and a good balance group, based on the lowest seventy and the top seventy balance scores. Those with poor balance had seven times as many sprains as subjects with good balance. 44 In spite of strong findings for poor balance being associated with injury Williams found balance ability was not related to the risk of lower extremity injuries. 36

Hrysomallis 12 suggests that methodological factors may explain the conflict in findings. The results could be affected by the type of training program, frequency of the training program, the type of subject, and the measurement tool. For example, in a study of college athletes, by Beynnon, the NeuroCom balance system was used to analyze the center of gravity sway angle and anterior and posterior sway. However, it may have been more appropriate with possibly different results had he evaluated lateral and medial sway since he was studying injury reduction for ankle sprains. 40
Balance Training: Injured Subjects

Wester and Holme reported a fifty-four and seventy-six percent reduction in the risk for recurrent ankle sprains when balance training was used following an acute ankle sprain. Postural control was measured through a position sense test using an electrical torsometer, ankle isometric strength test using a isokinetic dynamometer, and postural sway calculated on a force plate. The balance training groups were compared to the non balance training group, results showed the balance training groups had better postural control than the control group, however, effect scores crossed zero bringing into question these results. In a study by Troop an eighty percent reduction in recurrent ankle sprains was found following a balance intervention program using a rocker board.

A study done by Bahar suggested that it is crucial to implement balance training for the first year following injury because the risk of recurrent injury is largely increased in the first twelve months following injury. It may also be beneficial to continue long term balance training because Bahar’s study also showed that balance training injury reduction rate continues to increase time for up to two years. At one year, to prevent one injury, approximately 25 subjects would need to be treated, but by the second year, only 11 subjects would need to be treated to prevent one injury.

There is strong evidence that balance training following acute injury is crucial for rehabilitation, however, evidence is controversial when it comes to chronic injury, especially chronic ankle instability. According to McKeon anywhere from a weak to a strong effect was found between pre balance training and post balance training measures for those with chronic ankle instability. Thus, there is no conclusive
evidence to prove balance training improves postural control in chronic ankle instability. Bernier, in his study examining chronic ankle stability and balance training, found that some athletes responded well to balance training leading to significant postural stability gains, however, there were others that did not improve with balance training. Most of the evidence found for chronic ankle instability shows a trend toward postural stability improvements with training, however much of the data is inconclusive when it comes to actual significance because the effect size crosses zero which brings into question the results.

**Balance training programs**

Balance training exercises used to accomplish neural adaptations can be categorized into different kinds of balance training. There is static balance training, and dynamic balance training; however, some researchers have gone as far as to break down dynamic balance training into semi-dynamic and dynamic balance training. Static balance involves holding as still as possible on a stable, level surface, for example standing on one leg on a wood floor. Semi-dynamic balance involves standing as still as possible on a non fixed base, for example standing on an Airex pad. Dynamic balance involves the participant moving either on a fixed or unfixed base, for example jumping.

Exercises for balance improvement include strengthening exercises like theraband, calf raises, or weight circles. They also include, proprioceptive exercises, which utilize equipment such as foam surfaces, ½ foam roll surface, balance discs such as the DynaDiscs, wobble boards with varying sizes and shape for bases, and a mini trampoline. These exercises can be done with eyes open, eyes closed, and
could use ball tosses or object pickups.\textsuperscript{7,16,13,6,8} Balance training programs can include core exercises such as exercises which target the gluteus medius and transverse abdomen or lower extremity strengthening such as ball squats and lunges.\textsuperscript{16,9} Training programs may include exercises where the base is stable, but the body moves, as in the SEBT which challenges the postural control system through internal forces, or exercises where the base is unstable and the participant attempts to maintain stability, which challenges the postural control system through external forces. Balance training can also include dynamic exercise such as jumping and landing techniques, 4-square hops, as well as, running, and agility drills.\textsuperscript{16}

Although there is not magic number for the duration of balance training needed for postural stability gains, DiDtefano, after a systematic review of literature, concluded that length and duration of balance training does not seem to effect the amount of balance training gains, but stated the minimum amount of training he found to improve postural stability is 10 min a day, three times a week, for 4 weeks. Other studies have shown similar finding with reduction in injury risk with programs lasting as little as four weeks of training, with sessions ranging from two times weekly, to every day.\textsuperscript{7,8,13,6,41} Both home based balance training and supervised balance training improve balance and/or help in injury prevention, however, supervised balance training programs seem to bring more consistent balance improvements.\textsuperscript{9}

Holme achieved preventative effects in his study from only two times weekly supervised balance training and Wester achieved preventative effects with fifteen minutes daily at home balance training.\textsuperscript{41,11} McKeon states that six to eight weeks of
balance training reduces rates of recurrent injuries. Rationale is generally not provided to justify the duration of program.

A study by Malliou showed that in tennis players it does not matter whether the balance training program is done before or after practice sessions, balance gains are equal. Gioftsidou, he showed balance improvements with soccer players regardless of whether the balance training was done before or after practice however he found greater balance improvements with the group that did their balance training after practice than the group that did it before practice.

Dynamic stability has been shown to improve when balance exercises are performed on an unstable surface or on a combination of stable and unstable surface exercises. Dynamic stability also improves with balance training on a stable surface as shown with Brumels research using the Wii Fit and dance dance revolution.

**Traditional Balance Training Exercises**

Traditional balance training is often done on a combination of stable and unstable surfaces. Traditional balance often includes both single and double limb stance. Balance task can be performed with eyes open and or with eyes closed. When you close your eyes, balance becomes more difficult because the body has to rely on vestibular and somatosensory cues only due to the lack of visual cues. Some tools used for balancing on unstable surfaces include wobble boards, and tilt boards, foam surfaces, and ½ foam rolls. Traditional balance training often incorporates doing a task with ones hands, like catching a ball, while also attempting to balance.
Limitations to traditional balance training

Although traditional balance training has been shown to be an effective tool for injury rehabilitation, and injury prevention; traditional balance training becomes boring to the patient.\textsuperscript{43} Lack of interest or enjoyment in rehabilitation exercises can result in a lack of motivation to improve and decreased compliance.\textsuperscript{43}

Gaming as a Rehabilitation Tool

Using gaming for balance training improves balance and increases motivation for rehabilitation.\textsuperscript{14, 18, 15, 8} Betkers did a single subject design study in 2006 that showed lower fall count, decreased center of pressure exertion limits for some tasks, increased practice volume, and increased attention span during training.\textsuperscript{18} Brumel’s study, comparing gaming for balance training to traditional balance training, showed balance improvements from pre to post test in both gaming groups, and showed that subjects enjoyed the gaming training, were more engaged during the gaming training, and perceived the gaming program as less difficult than the traditional balance group.\textsuperscript{8} In Betkers study, in which he used gaming for rehabilitation for patients with chronic spinal cord and traumatic brain injuries, he found that dynamic balance improved and that patients exhibited an increase in practice volume and attention span during game based training.\textsuperscript{14}

Wii Fit Training:

There is a vast amount of research published on traditional balance training and some research on gaming used for rehab, but there is not much published about Wii Fit. Most research done with Wii Fit has been done using Wii Sports and looked at whether Wii Fit is a good exercise tool, especially in the elderly.
The one published study that evaluated Wii Fit balance games is Brumels’s study. Brumels did a study comparing traditional and two types of video game based balance programs (Wii Fit and Dance Dance Revolution). Brumels’s purpose was to compare the efficacy of traditional and video game based balance training programs to improve balance performance measurements and compliance. This study used twenty five subjects who were randomly assigned to the control, the Dance Dance Revolution group, or the Wii Fit group. The control used seven subjects; the traditional used five subjects; the Dance Dance Revolution used seven subjects; and the Wii Fit used six subjects.

Participants were pre and post tested using Star Excursion Balance Training and force plate data. Balance training sessions occurred three times per week for four weeks. Each balance training session lasted twelve to fifteen minutes. Participants were allowed rest between exercises, however, time was stopped and it was not counted toward their twelve to fifteen minute program. Participant’s age ranged from eighteen to twenty four years. All participants were non athletes and were not currently participation in any formal strength or cardiovascular.

The Traditional Balance training program consisted of five exercises; SEBT, DynaDisc balance with eyes opened, DynaDisc balance with eyes closed, DynaDisc ball toss, and Dynadisc orbits. Each exercise was done for three minutes.

Dance Dance Revolution (DDR) was modified so it could be played while balancing on one foot. Participants had four directions they could jump directed by the arrows on the screen. Subjects performed thee repetitions of three different songs.
The Wii Fit training program consisted of three games each played four to five minutes. The games included ski slalom, table tilt, and balance bubble. Following the four week training program and post testing a questionnaire was emailed to the subjects requesting feedback on their balance training program. The message read "please reflect on the exercise activity you were asked to perform during the 4-week training session and answer the following questions. Please use the following numbers to explain your response: 1=not very, 2=Mildly, 3=Somewhat, 4=Moderately, 5=very." The questions were; How difficult was your program? How engaged were you during your program? And how enjoyable was your program? Video game based training was perceived as significantly less difficult, and more enjoyable than traditional balance training.

Postural sway reduction for average displacement and average deviation on the y-axis was observed in the DDR group but no significant differences in pre/post scores on the SEBT were noted. Average deviation improvements were noted in the Wii Fit group, but no significant differences in pre/post SEBT scores were noted. No pre/post improvements in postural sway for the traditional group were found, however, there was a significant difference between pre/post star excursion test scores for the traditional group.

Brumels's study was a great start, but there is still much research needed in examining gaming, specifically Wii Fit training, used for balance gains. Brumel used his test in his training protocol for the traditional group, so they were training for the test. Brumels motivation survey has not been established for reliability and validity so that
needs to be pilot studied. Also, Burmels used non athletes. Research is needed using athletes since balance is key in athletic performance.

Wii Fit is a relatively new video game, released for sale May 21st 2008. Wii Fit came out as an addition to the original Wii, which was released in 2006. Wii Fit is a video game consisting of a platform activated by a participant’s feet and controlled by change in a participant’s center of pressure. What appears on the television is controlled by movements on the balance board as you play the games. Wii Fit features four main categories of exercises; a balance category, a strength category, a yoga category, and a cardio category. A participant stands on the Wii Fit platform in a bilateral stance in order to complete various games from one of the four categories. As you spend time exercising, “Fit Credits” are earned that unlock additional exercises and activities within these categories.

While playing the games, audio and visual cues, on a television screen, are given for the participant to respond to by changing or maintaining their center of pressure. The difficulty increases as the level of play increases. A participant can create a profile called “Mii.” they can make the “Mii” look like them and then participate in games as that person.

There are numerous exercises to choose from but the nine balance games are of particular interest.

The Table Tilt game appears on the TV as a wood board with holes in it and multiple marbles on the wood board. The objective is to tilt the board in order to roll the marbles into the holes. This game is unlocked from start. The participant controls how the table tilts by adjusting their center of mass on the board by leaning forward,
backward, left, and right. The participant must carefully manipulate the board to roll the balls into the holes or the ball will drop off the side of the board. If the participant does allow a ball to drop off the side, the board will spin around 180 degrees, possibly causing other balls to fall off the table, and will then drop the fallen ball back onto the center of the table.44

The objective to Ski Jump is to ski down the mountain and jump at the end. This game is unlocked from the start. The participant maintains a crouched position while skiing down the mountain and ski slope. While skiing down the mountain, the participant should keep his weight forward & center in the blue circle zone, shown on the screen. This is done to obtain maximum speed. When the “Mii” hits the red zone at end of the slope the participant stands straight up quickly and leans forward to simulate jumping.44

The object of the Tilt City game is to get the appropriate colored balls in the matching colored pipes. The participant leans from left to right on the balance board and tilts the Wii remote left and right to get colored balls to fall into corresponding colored pipes. The number of balls and the speed in which they fall onto the screen increases to increase the difficulty as the game goes on.44

**Conclusion:**

Postural stability and balance are important components of athletic performance. However, they can be compromised due to musculoskeletal injuries, and age. Balance training can be used for healthy subjects in order to reduce the rate of injuries, or in injured subject, to aid in rehabilitation of injuries and help reduce the rate of re injury. Balance training can be done on both stable and unstable surfaces, however most
clinicians do not train on stable surfaces alone due to the ease of the exercises. Wii fit has made stable surface balance training more challenging. More research needs to be done on Wii fit to determine if it is more effective than unstable surface balance training.
References


APPENDIX C

CONSENT FORMS

CONSENT TO ACT AS A SUBJECT IN AN EXPERIMENTAL STUDY (test groups)


   Investigator’s Name: Marie N Kirby, ATC, LAT, EMT-B  Phone: (863) 370-3011
   Participant’s Name ___________________________  Date: __________________
   Data Collection Location: Biomechanics laboratory, Georgia Southern University

2. The investigators are attempting to study the effects of dynamic balance training, using stable and unstable training surfaces, on dynamic balance and dynamic postural stability.

3. I am being asked to participate in this study because I am a student-athlete at Georgia Southern University.

   If I agree to participate in this study, I will be asked to perform the Star Excursion Balance Test and Dynamic Stability Index following a jump landing task on two separate occasions (pre and post training). I will be randomly assigned to either the Wii Fit or wobble board training group and asked to complete 12 sessions of balance training on my assigned balance training surface. Each pre/post test lasts less than 15 minutes, and each training session lasts 15 minutes.

4. There is minimal risk associated with participating in this study. These tests include skill that athletes commonly perform during their sport activities. I understand that medical care is available in the event of injury resulting from research, but that neither financial compensation nor free medical treatment is provided. I also understand that I am not waiving any rights that I may have against the University for injury resulting from negligence of the University or investigators. Should medical care be required, I may contact Health Services at (912) 478 – 5641.

5. I understand that, at most, I will receive a coupon to a restaurant for a discount or free food item at the completion or each week of training and be entered into a gift card drawing at the completion of the study; however there is research that shows dynamic balance training may reduce injury rates and improve performance in some subjects. I will be provided my results, if I so request. The results of this study may benefit health care professionals in the best surface to use for training to improve dynamic balance and postural stability.
6. I will attend two testing sessions, one pre training and one post training, as well as 12 training sessions. All testing and training will be completed within a six week time frame.

7. I understand that all data concerning myself will be kept confidential and available only upon my written request to Barry Munkasy Ph.D. I understand that any information about my records will be handled in a confidential (private) manner consistent with medical records. The questionnaires will remain secure and confidential with Dr. Munkasy as allowable by Georgia state law.

8. If I have any questions about this research project, I may call Marie Kirby at (863) 370-3011 or Dr. Barry Munkasy at (912) 478-0985. If I have any questions or concerns about my rights as a research participant in this study it should be directed to the IRB Coordinator at the Office of Research Services and Sponsored Programs at (912) 478-0843.

9. I will not receive compensation for my participation in this project. I will be responsible for no additional costs for my participation in this project.

10. I understand that I do not have to participate in this project and my decision to participate is purely voluntary. At any time I can choose to end my participation by telling the primary investigator, Marie Kirby, or by telling any of the other investigators.

11. I understand that I may terminate participation in this study at anytime without prejudice to future care or any possible reimbursement of expenses, compensation, employment status, or course grade except provided herein, and that owing to the scientific nature of the study, the investigator may in his/her absolute discretion terminate the procedures and/or investigation at any time.

12. I understand there is no deception involved in this project.

13. I certify I am 18 years of age or older and I have read the preceding information, or it has been read to me, and understand its contents. Any questions I have pertaining to the research have been, and will continue to be, answered by the investigators listed at the beginning of this consent form.

14. I have been provided a copy of this form.


Principal Investigator
Marie N Kirby, ATC, LAT, EMT-B
1208 Hanner Fieldhouse
(863) 370-3011
Participant Signature ___________________________ Date ____________

I, the undersigned, verify that the above informed consent procedure has been followed

Investigator Signature ___________________________ Date ____________
CONSENT TO ACT AS A SUBJECT IN AN EXPERIMENTAL STUDY (control group)


   Investigator’s Name: Marie N Kirby, ATC, LAT, EMT  Phone: (863) 370-3011
   Participant’s Name ___________________________  Date: ____________
   Data Collection Location: Biomechanics laboratory, Georgia Southern University

2. The investigators are attempting to study the effects of dynamic balance training, using stable and unstable training surfaces, on dynamic balance and dynamic postural stability.

3. I am being asked to participate in this study because I am a student-athlete at Georgia Southern University.

   If I agree to participate in this study, I will be asked to perform the Star Excursion Balance Test and Dynamic Stability Index following a jump landing task on two separate occasions (approximately four weeks apart) in order to serve as a control group for a balance training program study being conducted.

4. There is minimal risk associated with participating in this study. These tests include skill that athletes commonly perform during their sport activities. I understand that medical care is available in the event of injury resulting from research, but that neither financial compensation nor free medical treatment is provided. I also understand that I am not waiving any rights that I may have against the University for injury resulting from negligence of the University or investigators. Should medical care be required, I may contact Health Services at (912) 478 – 5641.

5. I understand that the only direct benefit for participating in this study will be a coupon to a restaurant for a discount or free food item at the completion of my final test date; however the results of this study may benefit health care professionals in choosing the best training surface to improve dynamic balance and postural stability.

6. I will attend two testing sessions approximately four weeks apart.

7. I understand that all data concerning myself will be kept confidential and available only upon my written request to Barry Munkasy Ph.D. I understand that any information about my records will be handled in a confidential (private) manner consistent with medical records. The questionnaires will remain secure and confidential with Dr. Munkasy as allowable by Georgia state law.

8. If I have any questions about this research project, I may call Marie Kirby at (863) 370 – 3011 or Dr. Barry Munkasy at (912) 478-0985. If I have any questions concerning about my rights as a research participant in this study it should be directed...
to the IRB Coordinator at the Office of Research Services and Sponsored Programs at (912) 478-0843.

9. I will not receive compensation for my participation in this project. I will be responsible for no additional costs for my participation in this project.

10. I understand that I do not have to participate in this project and my decision to participate is purely voluntary. At any time I can choose to end my participation by telling the primary investigator, Marie Kirby, or by telling any of the other investigators.

11. I understand that I may terminate participation in this study at anytime without prejudice to future care or any possible reimbursement of expenses, compensation, employment status, or course grade except provided herein, and that owing to the scientific nature of the study, the investigator may in his/her absolute discretion terminate the procedures and/or investigation at any time.

12. I understand there is no deception involved in this project.

13. I certify I am 18 years of age or older and I have read the preceding information, or it has been read to me, and understand its contents. Any questions I have pertaining to the research have been, and will continue to be, answered by the investigators listed at the beginning of this consent form.

14. I have been provided a copy of this form.


Principal Investigator
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Thomas Buckley, Ed.D., ATC
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(912) 478 – 5268
tbuckley@Georgiasouthern.edu
I, the undersigned, verify that the above informed consent procedure has been followed.
APPENDIX D

MEDICAL HISTORY QUESTIONNAIRE

<table>
<thead>
<tr>
<th>Subject Initials: _____________________</th>
<th>Subject ID #__________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Testing: <strong><strong>/_____/</strong></strong>___</td>
<td></td>
</tr>
</tbody>
</table>

### A. Demographic Data

1. Subject Date of Birth: ____ /____/ ______
2. Age: ________ Gender: ________
3. Year in School: Freshman Sophomore Junior Senior 5th year Senior

### B. Injury History

1. Have you ever suffered an injury to your foot, ankle, leg, or knee? YES NO
   If YES, please describe: _________________________________________
   __________________________
2. Have you ever had surgery on your foot, ankle, leg, or knee? YES NO
   If YES, please describe: _________________________________________
   __________________________
3. Do you have any balance disorders? YES NO
   If YES, please describe: _________________________________________
   __________________________
4. Have you been diagnosed with a metabolic disorder? YES NO
   If YES, please describe: _________________________________________
   __________________________
5. Have you been diagnosed with a neurological disorder? YES NO
   If YES, please describe: _________________________________________
   __________________________
6. Have you been diagnosed with a vestibular disorder? YES NO
   If YES, please describe: _________________________________________
   __________________________
7. Are you currently taking any medications? YES NO
   If YES, please describe: _________________________________________
   __________________________
8. Do you have any other injuries or conditions that may affect your balance (Chronic ankle instability, concussion, exc…) YES NO
   If YES, please describe: _________________________________________
   __________________________
9. Do you have any injury keeping you from full participation in your sport? YES NO
   If YES, please describe: _________________________________________
   __________________________
APPENDIX E

FIGURES

Figure 1. Right leg stance modified Star Excursion Balance Test

Figure 2. Left leg stance modified Star Excursion Balance Test
Figure 3. Start stance modified Star Excursion Balance Test
Figure 4. Anterior reach modified Star Excursion Balance Test
Figure 5. Posteromedial reach modified Star Excursion Balance Test
Figure 6. Posterolateral reach modified Star Excursion Balance Test
Figure 7. Start stance Dynamic Postural Stability Index jump protocol
Figure 8. End/landing stance Dynamic Postural Stability Index jump protocol
Figure 9. Change in Posterior Lateral Reach for all groups (control, Unstable, Stable). There was a significant difference between the control and unstable groups, and the control and stable groups. There were no significant differences between the unstable and stable groups.
There was a significant difference between the control and unstable groups, and the control and stable groups. There were no significant differences between the unstable and stable groups.

Figure 10. Change in Posterior Medial Reach for all groups (control, Unstable, Stable).
Figure 11. Change in Anterior Reach for all groups (control, Unstable, Stable). There was a significant difference between the control and unstable groups. There were no significant differences between the control and stable groups and the unstable and stable groups.
Figure 12. Change in Total Reach for all groups (control, Unstable, Stable). There was a significant difference between the control and unstable groups, and the control and stable groups. There were no significant differences between the unstable and stable groups.
Figure 13. Change in the Medial Lateral Stability Index for all groups (control, Unstable, Stable). There were no significant differences between groups.

Main Effect: 
$P = .504$
Figure 14. Change in the Anterior Posterior Stability Index for all groups (control, Unstable, Stable). There were no significant differences between groups.
Figure 15. Change in the Vertical Stability Index for all groups (control, Unstable, Stable). There were no significant differences between groups.

Main Effect:
P = .837
Figure 16. Change in the Dynamic Postural Stability Index for all groups (control, Unstable, Stable). There were no significant differences between groups.
Figure 17. Interest/Enjoyment subscale of Intrinsic Motivation Inventory. There was a significant difference between the unstable and stable groups.
Figure 18. Perceived Competence subscale of Intrinsic Motivation Inventory. There was no significant difference between the unstable and stable groups.
Figure 19. Effort/Importance subscale of Intrinsic Motivation Inventory. There was no significant difference between the unstable and stable groups.

Main Effect: P = .79
Figure 20. Value/Usefulness subscale of Intrinsic Motivation Inventory. There was no significant difference between the unstable and stable groups.
APPENDIX F

INTRINSIC MOTIVATION INVENTORY

Interest/Enjoyment

1. I enjoyed doing this activity very much
2. This activity was fun to do.
3. I thought this was a boring activity. (R)
4. This activity did not hold my attention at all. (R)
5. I would describe this activity as very interesting.
6. I thought this activity was quite enjoyable.
7. While I was doing this activity, I was thinking about how much I enjoyed it.

Perceived Competence

8. I think I am pretty good at this activity.
9. I think I did pretty well at this activity, compared to other students.
10. After working at this activity for awhile, I felt pretty competent.
11. I am satisfied with my performance at this task.
12. I was pretty skilled at this activity.
13. This was an activity that I couldn’t do very well. (R)

Effort/Importance

14. I put a lot of effort into this.
15. I didn’t try very hard to do well at this activity. (R)
16. I tried very hard on this activity.
17. It was important to me to do well at this task.
18. I didn’t put much energy into this. (R)

Value/Usefulness

19. I believe this activity could be of some value to me.
20. I think that doing this activity is useful for balance/postural stability.
21. I think this is important to do because it can improve balance/postural stability.
22. I would be willing to do this again because it has some value to me.
23. I think doing this activity could help me to reduce injuries and improve performance.
24. I believe doing this activity could be beneficial to me.
25. I think this is an important activity.