DYNAMIC BALANCE OF BALLROOM DANCERS AND SOCCER PLAYERS

A Thesis in
Kinesiology
by
Amy A. Dykes

© 2015 Amy A. Dykes

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

August 2015
The thesis of Amy A. Dykes was reviewed and approved* by the following:

Sayers John Miller, III
Assistant Professor of Kinesiology
Thesis Adviser

William E. Buckley
Professor of Exercise and Sport Science and Health Education

Giampietro Luciano Vairo
Instructor of Kinesiology

Stephen J. Piazza
Professor of Kinesiology
Graduate Program Director

*Signatures are on file in the Graduate School.
Abstract

It is commonly believed that improved balance can enhance athletic performance and reduce injury risk. Some dance styles have overall lower injury rates than other sports, and dancers perform better during balance tests compared to other athletes. This has lead coaches to believe dance training can improve balance, coordination and performance in athletes of other sports; however the research comparing dance and athletic populations has provided inconclusive results. The purpose of this research was to compare the dynamic balance abilities of ballroom dancers and soccer players by using three different dynamic balance tests. In this study, we hypothesized that the ballroom dancers would have better balance over a stable base of support, but that soccer players would have better balance during changes in base of support. Three tests, a modified Star Excursion Balance Test, Step and Balance Test, and Balance Beam Test, were selected for this study to assess different aspects of dynamic balance used in sports. All tests were timed to emphasize stability when speed was important. Thirty recreational athletes (15 ballroom dancers and 15 soccer players) performed three balance tests while a researcher recorded the time to complete trials and the number of errors committed during trials. A Mann-Whitney test was performed to compare the median times and errors committed for each test between the two groups. The investigators found no significant difference in times or errors for any test between the two groups. The findings indicate the training received in both soccer and ballroom dance may lead to similar balance abilities, and that athletes pursuing cross-training to improve balance may see equal results by training in either soccer or ballroom dance. Findings may also suggest that ballroom dancers may possess different balance abilities than ballet and modern dancers.
# TABLE OF CONTENTS

List of Tables ................................................................................................................................................. v
List of Figures ................................................................................................................................................... vi
Acknowledgements ........................................................................................................................................... vii
Chapter 1: INTRODUCTION ............................................................................................................................ 1
Chapter 2: MATERIALS AND METHODS ......................................................................................................... 4
Chapter 3: RESULTS .......................................................................................................................................... 15
Chapter 4: DISCUSSION .................................................................................................................................... 17
Chapter 5: CONCLUSION ................................................................................................................................. 21
LITERATURE REVIEW .................................................................................................................................... 22
Appendix A: Screening Questionnaire .............................................................................................................. 40
Appendix B: Recruitment Flyer ........................................................................................................................ 42
Appendix C: Verbal Script .................................................................................................................................. 43
Appendix D: Consent for Research .................................................................................................................... 44
Appendix E: Data Collection Form .................................................................................................................. 50
References ......................................................................................................................................................... 53
List of Tables

Table 2.1: Participant demographic and anthropometric measures .......................... 6
Table 3.1: Time to complete dynamic balance tests .................................................. 15
Table 3.2: Errors committed during dynamic balance tests ...................................... 16
List of Figures

Figure 2-1: Layout of the grid for the SEBT ......................................................... 7
Figure 2-2: Image of participant demonstrating a reach for the SEBT ...................... 8
Figure 2-3: Image of participant demonstrating a neutral stance .................................10
Figure 2-4: Layout of the grid for the SBT .............................................................12
Figure 2-5: Image of participant demonstrating tandem stance .................................13
Acknowledgements

I would like to thank my committee for their assistance in completing this project. I would especially like to thank my advisor, Dr. Miller, for his guidance in this project for the past two years, in bringing this project to completion. Thank you, also, to Dr. Buckley and Dr. Vairo for their guidance and assistance in revisions and feedback throughout this project. Additionally, I would like to thank Thomas Newman for all the assistance he has provided with any task, large or small. I wouldn’t have reached this point without his endless help.

Finally, thank you to my family and friends for their support through the last two years. They have always been there when I’ve needed them, no matter what the time difference is between us. You’ve all played a huge role in getting me to the point I’m at today, and I hope you all take pride knowing the contribution you’ve made in helping me to complete this project.
Chapter 1: INTRODUCTION

It is commonly believed that improved balance can enhance athletic performance and reduce injury risk\textsuperscript{1-12}. It has also been suggested that balance skills are sport specific\textsuperscript{13,14}. Athletes with better dynamic balance ability are associated with lower risk of lower extremity injury\textsuperscript{1}. Dancers have fewer tears of the anterior cruciate ligament of the knee, and lower injury rates overall, than many sports\textsuperscript{15}. These findings lead many to conclude that dancers have better balance capabilities than other athletes\textsuperscript{15-17}. The findings also lead coaches and athletes to try dance training to improve their balance, coordination and athletic performance, including famous athletes such as Lynn Swann, Herschel Walker, and Willie Gault, who trained with major dance companies to enhance their professional sports careers\textsuperscript{18,19}. Recently, ballroom dance has increased in popularity due to the success of television programs, such as So You Think You Can Dance (Dick Clark Productions for Fox Broadcasting Company; 2005-2015) and Dancing with the Stars (British Broadcasting Company Worldwide for American Broadcasting Company; 2005-2015)\textsuperscript{20}. Many athletes have found great success in this program, winning 8 of 20 seasons in the shows history, due to their athletic backgrounds. The most successful athletes have included Jerry Rice (Season 2, 2\textsuperscript{nd} place, football), Emmitt Smith (Season 3, 1\textsuperscript{st} place, football), Apolo Anton Ohno (Season 4, 1\textsuperscript{st} place, speed skating), Hélio Castroneves (Season 5, 1\textsuperscript{st} place, Indy 500 racing), Jason Taylor (Season 5, 2\textsuperscript{nd} place, football), Kristi Yamaguchi (Season 5, 1\textsuperscript{st} place, figure skating), Warren Sapp (Season 6, 2\textsuperscript{nd} place, football), Shawn Johnson (Season 6, 1\textsuperscript{st} place; Season 15, 2\textsuperscript{nd} place, gymnastics), Evan Lysacek (Season 10, 2\textsuperscript{nd} place, figure skating), Hines Ward (Season 12, 1\textsuperscript{st} place, football), Donald Driver (Season 14, 1\textsuperscript{st} place, football), Amy Purdy (Season 18, 2\textsuperscript{nd} place, Paralympic snowboarding), and Meryl Davis (Season 18, 1\textsuperscript{st} place, ice dancing)\textsuperscript{21}.
Many researchers have conducted studies comparing the balance capabilities of different athletes, and have produced mixed results\textsuperscript{14,15,22}. While some researchers have identified better balance in dancers than athletes in other sports, this finding is only true for static balance measures, typically involving maintaining a single leg stance position for a period of time\textsuperscript{13,17}. Tests for dynamic balance, where the body segments are moved over a stable base of support, indicate that there is no significant difference between dancers and other athletes\textsuperscript{22}, or that dancers may have inferior balance compared to other athletes\textsuperscript{23}. Additionally, researchers have looked at ballet and modern dancers\textsuperscript{15-17,22,24-29}, but haven’t studied ballroom in the same ways. Ballet and modern dance are choreographed dances, while ballroom dance is a partnership, consisting of a leader and a follower, which must react to the movements of each other as they move around the floor. Due to these reaction-based movements, ballroom may be more similar to soccer than to ballet. Ballroom dance has been shown to improve balance and movement coordination in children\textsuperscript{30,31} through physical education programs, and in sedentary older adults\textsuperscript{32}, older adults with Parkinson’s disease\textsuperscript{33}, and older adults with multiple sclerosis\textsuperscript{34}; however, it has not been studied in a collegiate or young adult population. Ballroom dance has a movement pattern that more closely resembles that of soccer, and presents a style of dance that may be more likely to be continued into later years of life than ballet or modern dance would be.

Since dynamic balance is considered more important than static balance with regard to athletic performance and injury prevention\textsuperscript{1,13}, it is important to determine which individuals demonstrate better dynamic balance abilities, so that potential benefits of cross training can be considered. Although participation in ballroom dancing and soccer both appear to require high levels of dynamic balance ability, the specific dynamic abilities developed through participation in these two activities may differ qualitatively. Objectively measuring dynamic balance abilities
is necessary to identify potential differences between dancers and soccer players. The purpose of this research was to compare the dynamic balance abilities of ballroom dancers and soccer players using several tests that challenge dynamic balance capabilities in different ways\textsuperscript{35}. Each test was selected to highlight a different aspect of dynamic balance: maintaining postural equilibrium while moving body part segments over a stable, unchanging base of support (modified Star Excursion Balance Test), changing the base of support then regaining postural equilibrium (Step and Balance Test), and changing the base of support and maintaining postural equilibrium while traveling along a narrow support (Balance Beam Test). All tests were timed to emphasize stability during movement when speed was of importance. In this study, we hypothesized that ballroom dancers would have better dynamic balance over a stable, unchanging base of support, but that soccer players would have better dynamic balance in tasks requiring changes in their base of support because ballroom dancers have to help a specific position more frequently than soccer players, and soccer players are more likely to travel quickly over a changing base of support in running, cutting, passing, etc.
Chapter 2: MATERIALS AND METHODS

Experimental Design & Setting:

This study utilized a cohort design, where groups were based on physical activity participation. Group assignment was the independent variable; participants participated in either ballroom dance or soccer. The dependent variables were the time to complete a modified Star Excursion Balance Test (mSEBT), Step and Balance Test (SBT) and Balance Beam Test (BBT), and the number of balance errors committed during each trial.

Participants were recruited from a university campus using the recruitment materials approved by the University’s Institutional Review Board (IRB) (Appendices B and C). Eligibility for participation in the study was assessed through the use of a screening questionnaire (Appendix A). Inclusion criteria were overall good health, between the ages of 18 and 40 years old, weekly participation and 5 years of experience in ballroom dance or soccer, and regular physical activity. Regular physical activity was considered three days a week of moderate-intensity activity for at least 30 minutes. Weekly sport participation for ballroom dancers often consisted of lessons or social dance gatherings, while soccer players often played pick-up games on campus soccer fields, with possible city-league play. Exclusion criteria were injury to the low back or lower extremity in the past 6 months, surgical procedures or concussions in the past 12 months, current pain or paresthesia to the lower extremity or low back, current treatment by a physician for any lower extremity or low back injury, and any other medical or neurological condition that affects balance or participation, including but not limited to pregnancy, heart conditions, and diabetes. Before enrolling in the study, all participants read and signed an IRB approved consent form (Appendix D).
Participants attended two 30-60 minute data collection sessions that were a minimum of 1, but no more than 7, days apart. Session spacing was designed to prevent fatigue. The initial session consisted of collection of demographic and anthropometric data as well as performance of the Star Excursion Balance Test (SEBT). The anthropometric measurements taken were height, mass, and leg length. Leg length was measured from the inferior border of the anterior superior iliac spine to the apex of the medial malleolus while the participant was lying supine. Body mass index (BMI) was calculated from height and mass data. Leg dominance was determined by asking the participant which foot they would use to kick a soccer ball. Session one concluded with the performance of the SEBT for baseline measurements after a 5-minute self-paced walking warm-up on a level treadmill (Woodway, USA, Waukesha, WI).

In the second session, participants performed a 5-minute self-paced walking warm-up on the level treadmill, and then performed the three tests of dynamic balance. The participants performed 3 practice trials and 3 official timed trials of the modified Star Excursion Balance Test (mSEBT), Step and Balance Test (SBT), and Balance Beam Test (BBT). They were given 30 seconds rest between trials, and a 3-minute break between practice and official trials, and a 3-minute break between the different types of tests. The order of the tests was randomized, using a random number generator, to prevent order effects. The researcher demonstrated each test for participants before they were asked to perform them.

Participants:
Thirty participants, 17 males and 13 females, met all inclusion and no exclusion criteria, and were enrolled in this study. Fifteen participants participated in ballroom dance on a regular basis and the other 15 participated regularly in soccer. Participants had a mean age of 23.97 ± 4.12
years and a mean BMI of 25.12 ± 2.58. Descriptive statistics and frequencies for participants are shown in Table 2.1. No significant differences were found between the groups with regard to age, height, mass, BMI, or leg length, but the gender balance between groups was different.

**Table 2.1: Participant demographic and anthropometric measures**

<table>
<thead>
<tr>
<th>Sex (M/F)</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
<th>BMI (units)</th>
<th>Leg Length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soccer</td>
<td>13/2</td>
<td>23.13 ± 3.16</td>
<td>174.13 ± 10.45</td>
<td>77.80 ± 12.74</td>
<td>25.53 ± 2.77</td>
</tr>
<tr>
<td>Dance</td>
<td>4/11</td>
<td>24.8 ± 4.87</td>
<td>156.81 ± 26.51</td>
<td>66.25 ± 7.84</td>
<td>24.71 ± 2.39</td>
</tr>
<tr>
<td>Total</td>
<td>17/13</td>
<td>23.97 ± 4.12</td>
<td>165.5 ± 22.21</td>
<td>71.97 ± 12.14</td>
<td>25.12 ± 2.58</td>
</tr>
</tbody>
</table>

*P*-Value: 0.252 0.99 0.365 0.654 0.477

Values are mean ± standard deviation
M/F = Male/Female
Statistical significance denoted at (*P* > 0.05)

**Testing Measures:**

Star Excursion Balance Test (SEBT)$^{24,36}$

The SEBT is a measure of dynamic balance in which the participant is asked to balance on one leg and reach as far as they can in a designated direction. The distance reached is the measurement taken during this test. The SEBT has been shown to be reliable$^{37}$. It has also been shown to be a valid discriminating test for chronic ankle instability$^{38}$. Reach data is typically normalized by leg length when making comparisons between groups$^{39}$.

During SEBT testing, the participant stood on their dominant leg in the center of a grid with 8 lines extending at 45° angles from the center of the grid (Figure 2-1). A 12-inch by 12-inch (30.48 cm by 30.48 cm) box was marked in the center of the grid to mark proper foot
placement. The grid was constructed using 2-inch (5.08 cm) wide athletic adhesive tape.

Participants were instructed to stand on their dominant leg in the center of the box and reach with their non-dominant leg as far as they can along each of the 8 lines with a light touch of the floor at the endpoint (Figure 2-2). Participants performed each reach sequentially in a clockwise direction. The researcher measured the distance in each direction to the nearest millimeter.

Distances were measured from the edge of the box to the mark made for each reach. The researcher provided verbal instructions and a visual demonstration on how to perform the task. Participants were instructed to keep their standing foot flat on the floor, trunk facing forward, and hands on their hips throughout each trial. Four practice trials and 3 measured trials were performed in each of the 8 directions. A 30-second break was provided between each trial, and a 3-minute break between the last practice trial and the first measured trial.

Figure 2-1: Layout of the grid for the SEBT
Trials were discarded and repeated if a balance error occurred during the trial. A balance error was judged to occur if the participant was unable to maintain balance and needed to bear weight on the reaching leg, touched down with the reach leg in a manner that allowed it to support body weight, toe touch did not occur on the marked line, the hands came off the hips, or the heel came off the ground during the test. The researcher calculated the average of the three measured trials in each of the 8 directions.

**Modified Star Excursion Balance Test (mSEBT)**

There have been several proposed modifications to the SEBT\textsuperscript{24,37}. In this study, the modification will refer to the change in the measured variable: the SEBT measures distance
reached, while this mSEBT measures time to complete the reaches in all 8 directions in a continuous fashion. Participants of this mSEBT have been shown to reach at lengths that were not significantly different from the standard SEBT, allowing researchers to focus on another variable (i.e. time) when evaluating balance\textsuperscript{24}. As this is a novel variation, reliability and validity for this test have not been established, however, it was shown that when asked to complete the SEBT for time, there was no significant difference in distance reached between the timed and untimed tests when testing the balance of trained ballet dancers\textsuperscript{24}.

Using the same grid as the SEBT, a line was marked with 1.5 inch (3.81 cm) wide athletic adhesive tape in each of the 8 directions at 90\% of the participant’s recorded average reaching distance from the SEBT during the first testing session, to ensure consistency in effort between participants. Participants were to stand on their dominant leg in the center of the box in the grid and reach with their non-dominant leg along each of the 8 lines in a counter clockwise direction with a light touch of the floor at the endpoint. They were instructed to reach with their non-dominant leg to at least the marked distance in each direction and return to a neutral stance for 2 seconds before continuing to the next line. The researcher did a 2-second count and gave a verbal cue to the participant when they could perform the next reach. A neutral stance was defined as standing in a single leg stance on the dominant leg in the center of the grid; the non-dominant leg could not touch the floor, and the 2-second count could not begin until there was less than 30° of hip flexion or abduction, with both the heel and forefoot of the dominant foot on the ground, and shoulders aligned over the hips (Figure 2-3). Participants were asked to complete the task as quickly and accurately as possible. Errors were counted if the participant was unable to maintain balance and needed to bear weight on the reach leg, touched down with the reach leg in a manner that allowed it to support body weight, toe touch did not occur on or beyond the
marked line, the hands came off the hips, or the heel came off the ground during the test. If the participant made an error, they had to repeat the reach in the same direction before continuing to the next line while the clock continued to run. Completion time and number of errors committed were recorded for each official trial.

Figure 2-3: Participant demonstrating a single-leg neutral stance

Step and Balance Test

The SBT is a novel dynamic balance test requiring participants to change their base of support and regain their postural equilibrium. Reliability and validity have not been established.

In the SBT, 6 inch by 6 inch (15.24 cm by 15.24 cm) boxes were marked with 1.5 inch (3.81 cm) wide athletic adhesive tape along lines at the same 45° angles used in the SEBT using only the anterior, anteromedial, medial, posteromedial, and posterior directions (5 total lines). The marked boxes were placed at the average reach length of the SEBT, and at 150% of that
average. Participants began standing on their dominant leg in the center of the grid and were then instructed to leap into the boxes along each line, landing on their non-dominant leg. After successfully landing in the designated box, subjects were given a verbal cue when the researcher determined that the subject completed a 2-second hold, and they were allowed to jump back to the center box, landing on their dominant leg. Subjects first moved into the closer anterior box (Fig. 2-4, Box 1), back to the center (Fig. 2-4, Box x), then the further anterior box (Fig. 2-4, Box 2), and back to center. This was then performed laterally (Fig. 2-4, Boxes 5-6), posteriorly (Fig. 2-4, Boxes 9-10), anterolaterally (Fig. 2-4, Boxes 3-4), and posterolaterally (Fig. 2-4, Boxes 7-8). Participants were required to hold a neutral, single-leg stance in each box and in the center of the grid for 2 seconds before continuing the test. A neutral stance was defined as standing in a single-leg stance where the free leg could not touch the floor, and the 2-second count could not begin until there was less than 30° of hip flexion or abduction, with both the heel and forefoot of the standing leg on the ground, and shoulders aligned over the hips (Figure 2-3). Participants were asked to perform the task as quickly and accurately as possible. Errors were counted if the participant’s foot was not touching the box when landing, if the free-leg touched the ground in a loss of balance, or if hands came of the hips. If the subject committed an error, they had to repeat the missed leap in the same direction before continuing to the next box. Completion time and errors committed were recorded for each official trial.
Figure 2-4: Layout of the grid for the SBT Balance Beam Test

The BBT adds challenge to balance testing by placing participants on a surface that is smaller than their natural base of support. This test is often used to assess motor development skills in children, but is also appropriate in assessing balance and control in adults\textsuperscript{40,41}.

In the BBT, a low balance beam (Nissen \textregistered Trampoline Rebound Tumbling Unit, Cedar Rapids, Iowa) was used for participants’ safety. The beam was an aluminum junior balance beam, 10 feet 9 inches (3.28 m) long, 2.75 inches (7.2 cm) wide, and 11 inches (28 cm) high, and is a size that is used in many physical education programs\textsuperscript{42}. Participants began on the ground facing the balance beam and had to step onto the balance beam and walk forward in a gait comfortable to them to the opposite end of the beam. They held a tandem stance (Figure 2-5), defined as the toe of one foot touching the heel of the other foot with the feet parallel, for 3 seconds until verbally instructed by the researcher to walk backwards to the starting end of the beam, and step back down to the ground. The timer started when both feet had left the ground,
and the timer was stopped when their first foot returned to the ground, to mark the time when the participant’s center of mass was over the balance beam. Balance errors were counted if the participant was unable to stay on the beam and touched the ground in the middle of the trial. If the participant made an error, they had to return to the last end of the beam they reached prior to the error, and start that direction over while the clock continued to run. Participants were instructed to complete the task as quickly as possible. Completion time and number of errors committed were recorded for each official trial.

Data Analysis:

Descriptive statistics, such as group means and standard deviations, were calculated for each of the dependent variables of interest. A Shapiro-Wilk test of normality was conducted, and it was determined that the data did not have a normal distribution; therefore, a Mann-Whitney U-test
was conducted to compare sample medians. All statistics were calculated using SPSS software (SPSS 22.0.0, IBM). An *a priori* alpha level of $P < 0.05$ was used to denote statistical significance.
Chapter 3: RESULTS

Dynamic Balance Tests for Time

A Shapiro-Wilk test of normality demonstrated that the data were not normally distributed, and therefore, a Mann-Whitney U-test was used to compare the median recorded times for each group in each dynamic balance test. No significant differences between the median times for completion (Table 3.1) were observed (mSEBT Time: \( P = 0.285 \); SBT Time: \( P = 0.186 \); BBT Time: \( P = 0.455 \)) for any of the dynamic balance tests.

<table>
<thead>
<tr>
<th></th>
<th>Soccer</th>
<th>Dance</th>
<th>P-Value</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>mSEBT (s)</td>
<td>31.98 ± 5.50</td>
<td>30.17 ± 6.58</td>
<td>0.285</td>
<td>(0.276, 0.294)</td>
</tr>
<tr>
<td></td>
<td>[30.76]</td>
<td>[29.60]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBT (s)</td>
<td>69.34 ± 10.37</td>
<td>63.91 ± 9.93</td>
<td>0.186</td>
<td>(0.179, 0.194)</td>
</tr>
<tr>
<td></td>
<td>[69.60]</td>
<td>[64.50]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BBT (s)</td>
<td>32.45 ± 25.06</td>
<td>33.46 ± 19.88</td>
<td>0.455</td>
<td>(0.455, 0.464)</td>
</tr>
<tr>
<td></td>
<td>[24.09]</td>
<td>[26.32]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

s = Seconds
Values are mean ± standard deviation and [median]
CI = 95% confidence interval
Statistical significance denoted at \( P < 0.05 \)
Dynamic Balance Tests for Committed Errors

A Shapiro-Wilk test of normality demonstrated that the data were not normally distributed, and therefore, a Mann-Whitney U-test was used to compare the median errors for each group in each dynamic balance test. No significant differences between the median number of errors committed (Table 3.2) were observed (mSEBT Errors: $P = 0.174$; SBT Errors: $P = 0.889$; BBT Errors: $P = 0.411$) for any of the dynamic balance tests.

**Table 3.2 Errors committed during dynamic balance tests**

<table>
<thead>
<tr>
<th></th>
<th>Soccer</th>
<th>Dance</th>
<th>$P$-Value</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>mSEBT (#e)</td>
<td>0.74 ± 0.64</td>
<td>0.47 ± 0.66</td>
<td>0.174</td>
<td>(0.166, 0.181)</td>
</tr>
<tr>
<td></td>
<td>[0.67]</td>
<td>[0.00]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBT (#e)</td>
<td>0.47 ± 0.60</td>
<td>0.42 ± 0.43</td>
<td>0.889</td>
<td>(0.883, 0.895)</td>
</tr>
<tr>
<td></td>
<td>[0.33]</td>
<td>[0.33]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BBT (#e)</td>
<td>0.78 ± 1.38</td>
<td>0.27 ± 0.61</td>
<td>0.411</td>
<td>(0.401, 0.421)</td>
</tr>
<tr>
<td></td>
<td>[0.00]</td>
<td>[0.00]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# e = Number of errors committed
Values are mean ± standard deviation and [median]
CI = 95% confidence interval
Statistical significance denoted at ($P < 0.05$)
Chapter 4: DISCUSSION

It was hypothesized that ballroom dancers would have better dynamic balance over a stable, unchanging base of support because they hold specific positions more frequently and for longer durations than soccer players. It was also hypothesized that soccer players would have better dynamic balance in tasks requiring changes in their base of support because they move at greater speeds than ballroom dancers when running, cutting, passing, etc. While it is often thought that dancers of some technique styles possess better balance skills than other athletes, these data suggest that both soccer players and ballroom dancers perform similarly on dynamic balance tests utilizing an unchanging base of support and a changing base of support if completion time and balance errors are the measured criteria. A factor that could contribute to this finding would be the effects of the choreographed steps in ballet, as opposed to the reaction-based steps when playing soccer or in ballroom dance, as well as the added variable of an opponent’s involvement in determining movement pattern in sports, or having to react to the movements of a partner in ballroom dance.

The findings of this study are consistent with other studies of dynamic balance in soccer players, showing that they have dynamic balance skills comparable to other athletes with similar skills and patterns of movement. In other studies, soccer players have been found to be superior in dynamic balance ability to basketball players, but inferior in dynamic balance ability compared to volleyball players, and comparable in dynamic balance ability to gymnasts and field hockey players. There is still no definitive ranking comparison of dynamic balance abilities between many sports and activities. This study may also show that the movement patterns of ballroom dancers and ballet dancers may be different, as ballroom dancers in this study were comparable to soccer players in tests of dynamic balance, while the dynamic
balance ability of ballet dancers was found to be inferior to that of soccer players\textsuperscript{23}.

Ambegonkar et al\textsuperscript{15} found that dancers with ballet and modern dance training performed better than non-dancers in some directions of the SEBT, but not all directions. The findings of this study support the argument for specificity of balance abilities in participants of various sports and dance activities.

While it was not a measured variable, it was observed during testing that ballroom dancers and soccer players performed each test with a different strategy that was consistent within each group. Dancers executed slower movements that emphasized stability and accuracy, with a straight, upright posture. Soccer players executed more rapid movements, which resulted in more deviations from the neutral stance and required more time to become stabilized in-between movements. This is consistent with the work of Chander et al\textsuperscript{23} who found that dancers were slower in adapting to perturbations than soccer players and volleyball players. Chander et al\textsuperscript{23} also found that dancers (trained in ballet and modern technique) performed better on static balance tests. The mSEBT and SBT required participants to hold a stable, unipedal stance for 2 seconds between every movement throughout the test, which may have been a disadvantage to soccer players who would typically not stop to obtain a static postural equilibrium. However, it is not established how the static or dynamic balance of ballroom dancers compares to that of ballet dancers, so this protocol may have been disadvantageous to the ballroom dancers, as well.

These data indicate that soccer athletes and ballroom dancers have similar dynamic balance skills, and athletes wishing to cross-train to improve their dynamic balance may see similar results from training in either soccer or ballroom dance. For example, since basketball players use similar movement patterns but demonstrate inferior dynamic balance abilities
compared to soccer players\textsuperscript{14,44}, they may benefit from cross-training in either ballroom dance or soccer as a means to improve their dynamic balance abilities.

**Limitations and Future Research**

Limitations and delimitations were present in the study that may have affected the results. The recreational status of the participants recruited could have affected results. While there was no significant difference between the groups in the performance outcomes in this study, a more advanced group of athletes may have produced different results. Different results may have been found if the researchers controlled for other concurrent dance training or sport participation, as balance abilities in the participants may have been developed from participation in these other activities. Studying recreational dancers, it was difficult to recruit participants trained in only one style, as they often train in more than one style over time (ballet, jazz, hip hop, ballroom, etc.), and no attempt was made to control for recreational participation in other sports for either group. In this study, only certain aspects of dynamic balance were studied. This study did not account for changes in the ocular system, dynamic balance during rapid movement (i.e. common agility tests), or tests that incorporate reaction time or simultaneous concentration on other tasks. Only the time and errors were evaluated in these novel and infrequently-used tests, and many other variables could have been measured. As these tests are novel tests or modifications, there are no data quantifying the reliability or validity of these protocols. These tests may not be reliable or valid measures of dynamic balance. This study did not utilize a control group of non-athletes for comparison. Previous studies have determined that athletes and trained individuals have better balance than non-athletes and untrained individuals\textsuperscript{45-47}. However, since these tests are not commonly used, including control subjects in these tests would be beneficial in future research,
as these tests have not been extensively studied. The lack of a control group limited our comparisons and our ability to determine if our participants had better dynamic balance abilities than inactive individuals. This study had more male than female participants, which may have affected data, as other researchers found that males performed better than females in the SEBT, even when reach lengths were normalized for limb length\textsuperscript{48}.

Future research is warranted to examine the balance abilities of dancers in differing styles to see if training in other styles could have different outcomes on both static and dynamic balance. More studies comparing the balance abilities of different sports and activities are warranted, as well as research comparing injury rates following balance training protocols, to look for potential benefits of training in different sports and activities. Studies should also examine the effect of training in other disciplines as a means of increasing balance by creating ballet, ballroom and soccer training programs for basketball players with poor dynamic balance\textsuperscript{14,44}, in order to see if their balance can improve through participation in other activities. Injury rates and performance testing measures for the season following this cross-training could then be compared to look for benefits of cross-training in soccer or different styles of dance. More sport specific tasks could be developed and incorporated into future testing to better replicate the movements of different groups of athletes. Sport specific assessments may better reveal the differences in balance capabilities between participants in different sports and activities.
Chapter 5: CONCLUSION

Balance is an acquired skill required of athletes of all sports and skill levels. It is important to assess the necessary balance skills for each sport when creating an athlete’s training protocol. In the protocol, it is important to individualize plans to fit the needs of each athlete, as the skill must be sport specific. Athletes wishing to cross-train in other disciplines for performance or injury prevention may see similar benefits from training in either ballroom dance or soccer, as ballroom dance training may promote dynamic balance abilities similar to those acquired with soccer participation.
LITERATURE REVIEW

Components of Balance and Postural Control

Balance is defined as “the ability to maintain the body’s center of gravity within its base of support”, either while stationary (static balance), or moving body segments through space (dynamic balance). Balance abilities are based on a person’s ability to interpret and react to visual, vestibular and proprioceptive inputs simultaneously to maintain postural stability and control of their movement. The interpretation and reaction to these stimuli is necessary to maintain postural stability. Postural stability is comprised of postural orientation, actively controlling the alignment and tone of the musculoskeletal system in response to gravity, support surface, visual information and internal references, and postural equilibrium, coordinating sensorimotor strategies to stabilize center of mass (COM) during movement and perturbations.

Sensory organs in the head are important in maintaining balance and postural equilibrium, and detect changes through the vestibular and ocular systems. Simultaneously, proprioceptive sensors in muscles, joints and connective tissue detect changes in joint movement and position. Together, these systems send afferent signals to the central nervous system (CNS) for interpretation and appropriate response. The cochlear system of the inner ear detects changes in velocity and acceleration of the head during movement. Otolith organs are responsible for the detection of linear acceleration, while the semicircular canals detect angular acceleration. Hair cells in these organs transmit signals to the vestibular nerve and are interpreted in the medulla of the cerebellum.

Proprioception is the portion of the somatosensory system that detects muscle tension and joint position from the skin and musculoskeletal structures and is especially responsible for sensing the body’s position in space and motion, including changes in velocity, acceleration,
muscular force, and joint displacement\textsuperscript{50}. Clinical testing of proprioception often requires participants to close their eyes during testing to eliminate visual input. This creates greater emphasis on CNS to use proprioception and vestibular inputs.

Stimulation of the retina is very important to balance control. Stimuli detected by the retina allow the brain to determine if motion is due to movement of the environment or self-motion. In addition to determining the presence and degree of movement experienced by the body, the ocular system is important in depth perception when gauging distances. Patients lacking full ocular function must learn to rely on other inputs for postural stability, and often have more accurate and sensitive interpretations of stimuli from the cochlear and proprioceptive systems. Similarly, in patients without full function of the cochlear system, there is a greater reliance on the ocular system for postural stability\textsuperscript{51,52}. In static balance, the ocular system is capable of reducing self-generated static sway by 50\%\textsuperscript{53}. In dynamic balance, the ocular system maintains a steady-gaze while the rest of the body is in motion.

Beyond the systems that contribute to balance ability, it is important to assess the properties of biomechanics and kinesiology that are involved in postural stability. This includes the models for explaining postural ability and the muscles acting on these models.

**Balance Strategy**

Human balance control is modeled as an inverted pendulum model with a closed-loop feedback system. Postural equilibrium is the ability to keep the center of mass (COM) over their base of support (BOS), an inverted pendulum\textsuperscript{54-56}. In the closed-loop feedback system, the mechanoreceptors of the musculoskeletal system send signals to the CNS, which controls the muscle reactions. Skeletal muscles sense external forces and respond with either contraction or
relaxation to maintain postural stability, such as using a contraction of the gastrocnemius when anterior motion is sensed\textsuperscript{57}. In this system, humans are capable of subconsciously maintaining standing balance under the influence of outside forces including perturbations and the force of gravity\textsuperscript{58}.

In accordance with these models, balance and postural stability are maintained primarily by the musculature of the hip and ankle through hip strategy, ankle strategy, and stepping strategy. These automatic postural responses involve activation of synergistic patterns of trunk and lower extremity muscles. Hip abductors and lateral rotators, and ankle invertors and evertors, control movements in the frontal plane, while the muscles responsible for hip flexion and extension, and ankle plantarflexion and dorsiflexion, control movements in the sagittal plane.\textsuperscript{59}

The ankle serves as the primary attempt to maintain ankle strategy, but when external forces exceed the eccentric force production of muscles of the ankle, the muscles of the hip are activated to provide additional control of the head, arms and trunk (HAT) to allow the ankle to better manage the COM over the BOS. Athletes with the ability to control more forces with ankle musculature require less activity by the muscles of the hip. Similarly, athletes that use hip strategy for stability of the HAT during movement relieve some of the strain placed on the ankle.\textsuperscript{60} Within these strategies, ankle strategy is most useful for small adjustments to COM, while hip strategy is most useful for large, quick adjustments of COM.

In the anterior/posterior direction, primary muscles of the ankle, gastrocnemius and tibialis anterior (TA), are assisted by the hip flexors and extensors, including rectus femoris, iliopsoas, biceps femoris and gluteus maximus. The contraction of the hip flexors or extensors causes respective flexion or extension of the hip joint to compensate for the acting forces. The lean of the trunk caused by this interaction aids in keeping the COM over the base of support. A
similar strategy is used in the lateral/medial direction with the abductors and external rotators of the hip (hip adductors play a very minor role in postural stability), and the peroneal and tibialis muscles of the ankle. If someone cannot keep their COM over their BOS using the ankle or hip strategy, they must change their BOS by taking a step; this is called stepping strategy.

Lee and Powers found that females with weaker hip muscles had greater activation of the peroneus longus and tibialis anterior, compensating for the lack of proximal stability with increased mechanical strain on distal joint musculature. This imbalance results in greater displacement of the subjects’ center of pressure (COP), and may indicate a greater increase in likelihood of injury, as it has been found that greater movements of the COP are predictive of ankle sprain risk. This is due to the inability of the gluteus medius muscle to control large movements within the frontal plane, the direction in which ankle sprains occur. The gluteus medius is located more proximal to the body’s center of mass than ankle musculature, and is therefore more efficient in controlling the weight distribution of the trunk and head through the lower extremity, reducing the required force of the muscles in the ankle to control the body’s stability. With insufficient strength to control the lateral movements required in various sport activities, the muscles in the ankle are required to exert more force to compensate for the body weight, and if muscular strength is insufficient to compensate for the force, lower extremity injury ensues.

Together, these strategies provide options for fine-tuning movement into a coordinated pattern that allows for the fluid movement patterns necessary in sport. Development of skill in each strategy is important in high-levels of sport performance, although the more commonly used strategies may vary from one sport to another.
**Balance Assessment**

While the mechanisms of balance have been well established, so have clinical evaluation tools that aid practitioners in the daily assessment of balance in patients. Balance is tested in a laboratory setting using devices that track postural sway (distance COM travels over the stable BOS) and time-to-boundary (amount of time required for COM to be within the BOS). Postural sway is measured during quiet standing in either a single-leg or dual-leg stance. Time-to-boundary is measured following a step or jump. These are measured using force plates, and are therefore not usable in most clinical settings. Clinically, static balance is frequently assessed using the Balance Error Scoring System (BESS)\(^{63}\). Dynamic balance has more varied options for assessment, but can include the Star Excursion Balance Test (SEBT)\(^{37}\), Y-Balance Test\(^{64}\), Modified Bass Test\(^{65}\), or Balance Beam Test\(^{40,41}\). These evaluations identify deficiencies, muscle imbalances, possibility of injury, and areas of potential to improve sport performance. Balance assessment is used to measure static and dynamic balance capabilities and compare them to other subjects or patients, or to established norms.

The BESS requires the participant to perform three standing postures first on a flat surface, then on an unstable surface, the foam Airex® pad (Airex, Switzerland). Participants perform the test in a double-leg stance (feet together), single-leg stance (standing on the non-dominant leg), and tandem stance (non-dominant foot behind the dominant foot). They must keep their hands on their hips and their eyes closed for 20 seconds in each position, on both surfaces. Errors are counted if the participant opens their eyes, removes their hands from their hips, falls out of position, takes a step, lifts the forefoot or heel, fails to return to testing position within 5 seconds, or abducts the hip more than 30°. BESS is classified as having good intratester reliability (ICC = 0.90)\(^{66}\), good intertester reliability (ICC = 0.85)\(^{66}\), and moderate test-retest
reliability ($G = 0.64$)\textsuperscript{67}. To increase the demands of proprioceptive responses, examiners will often utilize foam pads during assessments of standing balance, including the BESS\textsuperscript{63,68}. Other options for increasing difficulty in postural assessment include a Both-Sides Up (BOSU, Ashland, Ohio) trainer, an air-filled bladder, or half-foam roller. Stanek, Meyer and Lynall\textsuperscript{69} compared the subjects’ balance on the three different surfaces using center of pressure (COP) area and postural sway measures. They found that the BOSU poses the greatest challenge over the other two surfaces, and that the air-filled bladder was significantly more challenging for patients than the half-foam roller.

The SEBT requires participants to stand on their dominant leg in the center of a circle with designated lines spaced $45^\circ$ apart, creating a total of 8 lines. Participants reach with their non-dominant leg as far as they can and tap their toes along each line without shifting weight. The test is known for having good interrater reliability ($ICC = 0.86 - 0.92$)\textsuperscript{70} in predicting lower extremity injury and in identifying various lower extremity conditions.\textsuperscript{37} The SEBT is used as a screening tool for balance ability post-injury, especially in patients with chronic ankle instability (CAI)\textsuperscript{71} or returning from anterior cruciate ligament (ACL) reconstruction surgery\textsuperscript{72}. The SEBT can be used to identify stability and movement deficits in the injured limb when compared to the uninjured limb\textsuperscript{37}. The SEBT is also used to monitor progress within a rehabilitation protocol in patients with lower extremity injuries. The final common use of the SEBT is for the prediction of lower extremity injury, as demonstrated by McGuine et al\textsuperscript{6} and Plisky et al,\textsuperscript{73} who both found significantly increased probability of injury in high school basketball players with poor performance on the SEBT.

Batson\textsuperscript{24} developed modified variations of the SEBT to find a dance-specific screening tool to accurately assess balance abilities. Subjects were required to complete a standard SEBT
before performing the following variations: a timed-test to complete all 8 directions in a circular pattern as quickly and safely as possible, a timed test while answering questions aloud, and performing the pattern while standing on an Airex® balance pad at a self-determined pace. The timed-test modification showed the least variability and was shown to be a promising test for identifying balance deficits in dancers with or without history of lower extremity injury.

The Y-balance test is another modification of the SEBT, in which participants reach only in the anterior, posteromedial and posterolateral directions. This test was designed to eliminate redundancy in the SEBT by requiring reaches in 8 directions. Reaches in the anteromedial, medial, and, especially, posteromedial reach directions are most representative of reach deficits in patients with CAI\textsuperscript{74}. Similarly to the SEBT, test administrators are looking for asymmetry of reach, which could indicate potential for injury\textsuperscript{64,75}. The Y-balance test has good interrater test-retest reliability (ICC = 0.85-0.93)\textsuperscript{75}.

In one study, Gribble and Hertel\textsuperscript{39} found that male subjects had a significantly further reach in some directions than women, however, when results were normalized for leg length, there was no significant difference between men and women in the study. For this reason, when SEBT testing is focused on reaching distance, it is important to normalize data. When SEBT data is used to compare reaching distance between groups, it is typically normalized using leg length. However, in another study, Gorman et al\textsuperscript{48}, using the Y-balance test, found that males performed longer reach distances in the posteromedial and posterolateral directions, as well as in their composite reach distances, than female participants did.

The Bass Test requires participants to step along a pattern keeping their weight on the ball of their foot and holding at each marker for 5 seconds\textsuperscript{65,76}. Participants were given 5 points for each target they reached, and 1 point per second held (up to 5 seconds), for a total score of up
to 100 points. Errors were counted for missing targets, touching the ground with the heel of the standing foot when landing (5 points each), only partially covering a target (3 points), and 1 point each for balance errors (touching the ground with the heel of the standing foot during the 5-second hold, or moving the standing foot during the 5-second hold.)\textsuperscript{15} The Bass test has an acceptable reliability of 0.75\textsuperscript{65}. The modified Bass test simplifies the scoring used, and requires participants to complete the test on one leg, rather than jumping from one leg to the other. Researchers count 3 points for a balance error and 10 points for a landing error; lower scores indicate better dynamic balance. Landing errors consisted of not covering the tape mark completely, stumbling on landing, or landing, or inverting or everting the foot more than 10°. Balance errors included touching the ground with the non-dominant limb, touching the non-dominant limb to the dominant limb, or moving the non-dominant limb into excessive flexion, extension or abduction\textsuperscript{77}.

The Balance Beam Test (BBT) adds challenge to balance testing by placing participants on a surface that is smaller than their natural base of support. This test is often used to assess motor development skills in children, but is also appropriate in assessing balance and control in adults\textsuperscript{40,41}. Testing procedures can vary to adapt to different populations, and can include forward walking, backward walking, and/or a balance hold on the beam. This test challenges balance by creating a narrow platform that is smaller than participants’ normal BOS. Scoring can be based on time or pass/fail standards, where time does not matter\textsuperscript{40}. The balance beam is an apparatus used in women’s gymnastics\textsuperscript{78}, as well as in physical education curricula for children\textsuperscript{40,42}, and in determining the functional dynamic abilities in children with developmental disorders, such as intellectual disabilities\textsuperscript{79}.
These tests can be used by clinicians to identify weakness in balance ability and alter training protocols accordingly. Clinical measures of balance have proven to be valid and reliable methods of testing different aspects of patients’ balance abilities, and comparing these abilities to other populations, or patients’ other limb. Results of these tests can be implemented into programs for injury prevention, injury rehabilitation, and athletic performance improvement.

**Benefits of Balance Training**

Balance training is commonly utilized in injury prevention, rehabilitation, and sport performance programs\(^1\text{-}^5,^7\). In athletic populations, regular participation in balance exercises and training programs has been shown to reduce the risk of lower extremity injuries by 39%, the risk of acute knee injuries by 54%, and the risk of ankle sprains by 50%\(^1\). It can also reduce the risk of ACL injuries, especially in athletes with a history of ACL sprains\(^1\). Research suggests that athletes in sports that are at risk for lower extremity injuries should participate in balance training a minimum of one time per week for at least 3 months with sessions that are at least 10 minutes in length and include sport-specific drills\(^1^2\). Athletes performing balance training more frequently than the minimal recommendation saw greater improvements in balance ability, especially in tasks requiring closed eyes, unstable surfaces or dynamic balance.\(^2,^3\) Balance training can include exercises with tilt boards, unstable surfaces, and performing dynamic movements while maintaining a static stance, but plyometric exercises, agility drills, and sport specific tests should be included with balance programs for maximal results in injury prevention\(^80,^81\).

Following athletic injury, balance training is important in preventing reinjury. McKeon and Hertel\(^68\) report findings that indicate sport-specific balance training is important for
increasing performance following athletic injury, and a program should be implemented during the return to play progression. Additionally, Zech et al\textsuperscript{82} found that a rehabilitation program should include proprioception and neuromuscular training, such as perturbations and plyometric exercises, to increase joint functionality following ankle sprains to decrease the incidence of recurrent ankle sprains. Neuromuscular training was defined as programs that combined balance, strength, plyometrics, agility, strength, and sport-specific exercises. They also showed that following ACL reconstruction, including neuromuscular training and proprioceptive training in the standard rehabilitation protocol lead to decreased incidences of the knee giving way and improved jump performance\textsuperscript{81,82}.

More recent research has found that balance training may also increase performance in sports. When studying Turkish soccer players, Erkmen et al\textsuperscript{8} found a correlation between standing balance and better performance in vertical jump, triple-hop and standing broad jump, indicating that having better postural stability may be a significant factor for explosive power activity performance over athletes with poor balance posture.

Hrysomallis\textsuperscript{10} found that including a balance training component in activity programs lead to enhanced motor skills due to an increase in rate of force development. Improvements were seen in vertical jump, agility, shuttle run, and downhill slalom skiing\textsuperscript{83-86}. In another study, Evangelos et al\textsuperscript{11} studied amateur soccer players and found that players that completed a proprioception and balance program had improved accuracy and ability with juggling tasks, short passing accuracy, and long passing accuracy, indicating that a training program incorporating balance and proprioception can lead to higher levels of technical ability. A similar study conducted on basketball players found that a balance and proprioception training program resulted in more accurate passing skills during play\textsuperscript{12}.
While research may be inconclusive in the best type of exercises to perform for increased balance, it is clear that benefits of this type of training influence skills outside of the practiced balance task. Balance training has shown improvements in basic skills that form the fundamentals of many sport activities.

**Injuries Affecting Balance Mechanisms**

Injuries to the components of the postural control system all have effects that could continue to have an effect after the athlete has returned to full play. These injuries include ligament sprains, muscle strains, and concussions.

Ankle sprains are the most common injury in athletic populations; it is estimated that 30% of sports injuries are acute ankle sprains. Waterman et al found that over 49% of all ankle sprains occur during athletic events, while the remaining half occur during activities of daily living. Basketball is the sport that shows the greatest risk for ankle sprains. It is also known that multiple ankle sprains can increase the chances of developing CAI. Kobayashi and Gamada found that CAI can be traced to multiple causes, including mechanical instability, decreased muscle strength in the ankle and hip, poor postural control, and neuromuscular and proprioceptive deficits. CAI leads to an unstable feeling or “giving way” in the ankle, and an increased chance of injury to the lower extremity. Damage to the ligament results in damage to the proprioceptors in the tissue, altering communication to the CNS. This can be bilateral, even if only one side is injured. Wikstrom et al found that deficits in postural control can also be found in the uninvolved limb following ankle injury, and that clinicians treating ankle sprains should assess postural control of both limbs when creating a return to play protocol; they additionally concluded that the uninvolved limb should not be used as a measurement of the patient’s
“normal” postural control, as it may have its own deficits even without injury. Measurements of patients’ postural control should be compared to standardized norms of each test conducted.

Weak hip musculature has been shown as a predictor for injury to the ACL in the knee. Inability of hip musculature, primarily gluteus medius, to control the distribution of the weight of the trunk and head leads to improper loading of the knee joint during activity. Weakness in hip abductors and external rotators causes excessive adduction and internal rotation. This change in joint position can lead to an ipsilateral trunk lean during activities like walking, running and jumping. This trunk lean increases COP movement during activity, and places the lower extremity at greater risk for injury at either the ankle or knee.

Mild traumatic brain injury (mTBI) also affects balance ability. According to Catena et al, children diagnosed with mTBI show deficits in balance control for up to 12 weeks post-injury and children with severe traumatic brain injury can show these deficits for approximately one year. Alsalaheen et al report that up to 81% of concussion cases experience dizziness after injury, and up to one third of these cases can have symptoms that persist for up to 5 years even though most concussion cases report a resolution of these symptoms within a few weeks. The balance and postural stability deficits present after concussion are a result of altered sensory integration ability. Guskiewicz discussed three sensory systems in the brain that communicate to coordinate balance and postural control: the first system consists of the areas of the brain that are responsible for attention, concentration, memory and emotion, the second consists of the sensorimotor cortex, cerebellum and basal ganglia, and the third system consists of the brainstem and spinal cord. A disruption in the communication of these systems, caused by some degree of trauma to these structures, can then cause postural instability and poor balance.
An injury to any tissue that plays a role in balance and postural control affects communication to the other components of the system. When clinicians are evaluating patients for a return to play progression, it is important to consider the interactions between the systems as a whole, not solely treating the injured body part.

**Comparison of Balance Abilities in Athletic Populations**

With skill requirements varying among sports, it is no surprise that different balance abilities can be observed in different sports and activities. It is important to review the current knowledge in balance abilities in varying populations in order to appropriately prepare teams to perform at peak performance and avoid common injuries.

Dancers are commonly thought to have better balance than most other athletes\textsuperscript{16,27}. When compared to active non-dancers, Ambegonkar et al\textsuperscript{15} found dancers had better scores in the BESS test and some SEBT directions, but not in all directions. Dancers were found to have results similar to non-dancers in the modified Bass Test of dynamic balance\textsuperscript{15}. Another study\textsuperscript{16} compared dancers and non-dancers using a single leg balance task that incorporated a variety of proprioceptive challenges, and found that dancers showed significantly better static balance abilities. Lin et al\textsuperscript{27} studied a single leg stance in dancers, and found that experienced dancers have similar postural stability between their dominant and non-dominant leg and that their balance exceeded novice dancers. In the novice dancers in this study, non-dominant leg balance was similar to experienced dancers, but they had less ability to balance on their dominant leg. De Silveira Costa, Ferreira and Felicio\textsuperscript{17} state that dancers possess better static balance than non-dancers, but they are also more vision-dependent in their balance ability than other athletes. Chander et al\textsuperscript{23} assessed the static and dynamic balance of female collegiate soccer players,
volleyball players and dancers using COP sway measurements during unilateral stance with eyes open and closed (static balance), and during bilateral stance with perturbations from the platform upon which they stood (dynamic balance). Dancers and volleyball players performed significantly better than soccer players in static balance testing with eyes open, but there were no significant differences between groups when eyes were closed. In dynamic balance, dancers actually performed slower in this test than the other athletes, resulting in inferior scores than the other groups.

While most studies primarily assess young adult or collegiate dancers trained in ballet or modern dance, some studies have looked at different styles of ballroom dance and their effects on balance in different populations. Aldemir et al.\textsuperscript{31} evaluated a dance education program in physical education classes for pre-adolescent and adolescent children and its effects on motor performance. Children that did not participate in extra-curricular activities were assigned to a dance group or control group to complete their 20-week program. Children were assessed before and after the program for their flexibility, dynamic balance, agility, speed, strength, and other measures. There was no significant difference in dynamic balance between the dance and control group for pre-adolescent children, although the dance group saw greater improvements in all other areas than the control group. In adolescent children, the dance group saw significantly more improvement in dynamic balance than the control group, in addition to improvements in many of the other variables measured.\textsuperscript{31} Walaszek and Nosal\textsuperscript{30} studied eight-year-old children that completed one year of training in the dance style of acrobatic rock’n’roll, comparing their motor coordination abilities to a group of children that did not participate in any similar styles of dance. After the one-year training program, boys and girls completing the acrobatic rock’n’roll
dance training performed significantly better on tests and had a higher level of motor coordination than the other children of the same age\textsuperscript{30}.

Ballroom dance has also been studied in older adults as a means of improving their quality of life. Da Silva Borges et al\textsuperscript{32} used balance assessment following a ballroom dance program as a measure of determining functional autonomy of institutionalized, sedentary elderly adults. Participants trained 3 times per week for 50 minutes, learning the styles of foxtrot, waltz, rumba, swing, samba and bolero during the 8-month period. Only the dance program group saw significant improvements in the time to complete designated balance tests (tested on a stabilometer) and in the Latin American Group for Maturity (GDLAM), which was used to assess functional autonomy, indicating an improvement to the quality of life in sedentary elderly adults by beginning a ballroom dance program. Other studies have used ballroom dance to improve movement-quality, balance, and quality of life in patients with Parkinson’s disease (PD). Hackney and Earhart\textsuperscript{33} compared the effects of training in either Argentine tango or American ballroom (waltz and foxtrot), or no dance training in controls, after a 13-week program. Participants in the dance training groups saw similar improvements in their balance and walking ability, but tango may produce slightly greater improvements in these areas. Both dance groups saw significantly more improvement than the control group\textsuperscript{33}. Mandelbaum et al\textsuperscript{34} performed a similar study in patients with multiple sclerosis (MS), implementing a 4-week salsa dance program, evaluating each participant’s gait, balance, physical activity, MS symptoms, and other variables. Variables were measured prior to their assignment in either the dance or control group, immediately after the intervention program, and at 3 and 6 months post-intervention. Participants of the dance group saw significant improvements in balance, gait, physical activity, and other symptoms when compared to the control group during all follow up testing sessions
(immediately after salsa dance program completion, 3 months after completion, and 6 months after completion.) This indicates that ballroom dance training may be a promising treatment plan for MS patients to improve their balance, gait and physical activity\textsuperscript{34}.

In other sports and young adult populations, Bressel et al\textsuperscript{14} compared collegiate soccer, basketball and gymnastics athletes’ balance abilities using the BESS and SEBT. While no significant differences were found in the static and dynamic balance of soccer players and gymnasts, basketball players scored significantly lower on both tests than the other groups. It was concluded that because basketball players do not routinely practice skills similar to these tests, they are less prepared for testing than other athletes. The researchers also concluded that since balance abilities were similar between soccer players and gymnasts, it is likely that these sports may have some sensorimotor challenges in common, or that the tests used were not sensitive to the activity style of the athletes in order to identify differences. Kachanathu et al\textsuperscript{44} studied male athletes and concluded that basketball players had static balance abilities comparable to soccer players, but they had inferior dynamic balance abilities compared to soccer players. Collegiate soccer players were also compared to collegiate field hockey players in the SEBT\textsuperscript{43}, and found to have no difference in reach distances in any directions or in their composite reach distances. However, when reach distances were normalized in this study, soccer players were inferior to field hockey players in posterior and lateral reach distances, suggesting that field hockey players have better dynamic balance abilities in those directions.

Zemkova\textsuperscript{13} takes into account that only a few sports, such as archery, shooting and dance, require athletes to maintain good static balance, and only dancers are required to maintain that stance on a single leg. Most sports are more dependent on good dynamic balance, and the specific balance skills are dependent on the athlete’s sport and position. Skating sports need high
accuracy in the control of their COM with the ability to maintain their COM over a single leg at times; equestrian sports require postural stability in a seated position; combat sports require stability amidst perturbations; many sports require balance in quick, side-to-side movements, including soccer, basketball, tennis, field hockey and volleyball; other sports, such as running, cycling and cross-country skiing, require athletes to be more resistant to fatigue of postural control muscles than other athletes.

An important aspect of athletic performance in children is the difference in training as a single-sport or multiple-sport athlete. Gorman et al48 studied the dynamic balance of these two groups using the aforementioned Y-balance test, finding that athletes participating in only one sport do not perform differently on the Y-balance test than athletes participating in multiple sports. They did find that males exhibited increased performance on the test compared to females, even when the data were normalized for leg length. However, it is not specified how long the athletes had been training as either single-sport or multiple-sport athletes, and the study included only high school athletes.

Balance has also been studied in a comparison of active and non-active, or athlete and non-athlete populations. Orr et al45 studied sedentary adults through a power-training regimen to observe changes in dynamic balance. Healthy adults were randomly assigned to exercise at 20% (low), 50% (medium), or 80% (high) of their maximum strength, or to a non-training control group. All individuals participating in a power training program saw an improvement in balance, measured on a Dynamic Balance System, a moving platform on which participants stood, over individuals that remained sedentary45. Palmer et al46 compared female collegiate soccer players and non-athletes, measuring the sway index of individuals in both groups. They found that collegiate athletes had significantly lower sway indexes than non-athlete controls, which may
have an effect on overall athletic potential. Additionally, Jakobsen and Krstrup\textsuperscript{47} studied non-active men, assigning participants to complete a 12-week soccer training program, continuous running program, high-intensity interval running program, or no training. Participants’ postural balance was measured with a force plate, measuring a 30-second single-leg stance for their COP sway path, and holding a 1-minute single-leg stance on a narrow beam while errors were counted. Participants of the soccer training and interval training programs saw significantly decreased sway paths in the first test, while all participants of a training program had fewer errors on the second test\textsuperscript{47}. Previous studies indicate that active adults performing any type of training or exercise program perform better in balance test than sedentary or non-active individuals\textsuperscript{45-47}.

This indicates that balance is a learned skill, specific to the sport an athlete trains in, but with possible carry-over effects into other disciplines. However, it is also indicated that athletes can develop balance skills by cross-training in other sports and activities. Finally, active adults perform better in balance tests than sedentary or untrained adults.
Appendix A: Screening Questionnaire

Dynamic Balance Comparison of Female Dancers and Soccer Players

Principal Investigator: Amy Dykes, ATC

As a general health and eligibility screen, you must be able to answer ‘YES’ to all of the following questions to be eligible for participation:

1. Are you recreationally active (defined as individuals engaging in physical activity at least three days per week for 30 minutes over the past six-months)?
   Yes   No

2. Are you between 18 and 40 years old?
   Yes   No

3. Do you have at least 5 years of experience in soccer, or dance training?
   Yes   No

4. Do you have weekly practice or take weekly lessons in soccer or dance?
   Yes   No

5. If you answered ‘YES’ to questions number 4 and 5, which sport are you trained in?
   □ Soccer   □ Dance

As a general health and eligibility screening, you must be able to answer ‘NO’ to all of the following questions to be eligible for participation:

1. Have you sustained any injury to the lower extremity or lower back within the last 6 months?
   Yes   No

2. Are you currently receiving aid, treatment or rehabilitation under the care of a physician for any lower extremity or lower back condition due to injury?
   Yes   No

3. Do you have any current pain or paresthesia in your lower extremity or lower back that is currently not being treated?
   Yes   No

4. Have you had any lower extremity or lower back surgeries in the past 6 months?
   Yes   No

5. Have you sustained a concussion within the last 12 months?
   Yes   No

6. Have you been diagnosed with any neurological disorders that result in dizziness, balance problems, or other symptoms?
   Yes   No
7. Are you currently pregnant? 
   Yes  No

8. Have you had any lower extremity or lower back surgeries in the past 12 months? 
   Yes  No

9. Have you ever been diagnosed with a heart condition, diabetes, or any other medical concern that could interfere with your participation in running or other activity? 
   Yes  No
Research Volunteers Needed

Do you participate in soccer or dance? If so, you may be interested in participating in our research study at Penn State.

Measurements: dynamic balance, functional tests

Purpose: Assess the dynamic balance of soccer players and dancers by measuring the time to complete specific tasks.

Requires one (2) 45-60 minute session in Room 39 of Recreation Building.

In order to qualify for the research study, you must meet the following criteria:

• Age 18 - 40
• Good general health
• Physically active
• Recreational participant of soccer or dance, with at least 5 years experience and participation at least once per week
• English speaking

Amy Dykes and Dr. Sayers John Miller
Departments of Kinesiology
Athletic Training & Sports Medicine

For more information, contact Amy Dykes by

Email: aad205@psu.edu or Phone: 925-337-5759
Appendix C: Verbal Script

Title of Project: Dynamic Balance Comparison of Dancers and Soccer Players

Principal Investigator: Amy Dykes, ATC

Project Coordinator: Sayers John Miller, PhD, PT, ATC

Co-Investigators: William E. Buckley, PhD, ATC Giampietro L. Vairo, PhD, ATC Thomas Newman, MS, ATC

Script: Recreational adults participating in soccer or dance

Hello, my name is Amy Dykes and I work with the Athletic Training Research Laboratory at Penn State. I am currently looking for research volunteers and was wondering if you would be interested in participating or at least hearing more about this study. I am looking for a group of participants who are 18 to 40 years of age and a recreational participant of soccer or dance. Participants in this study should be in generally good health, physically active, with no recent injuries to the lower extremity. I will be testing dynamic balance in three different tasks. If you are interested in participating, you will be required to come to Room 39 of Recreation Building for two visits of 45-60 minutes each. During the first session, you will be required to complete 4 practice trials to learn the pattern of the first test and complete 3 official trials to measure your baseline abilities for the study. During the second session, you will be asked to complete three practice trials, and three official, timed trials for each of the three tasks in this study. If you have any questions or need to get in touch with me for any reason, my phone number is (925)337-5759 and my e-mail is aad205@psu.edu. Thank you.
Appendix D: Consent for Research

CONSENT FOR RESEARCH
The Pennsylvania State University

Title of Project: Dynamic Balance Comparison of Female Dancers, Gymnasts and Soccer Players

Principal Investigator: Amy Dykes, ATC
Address: Department of Kinesiology
146 Recreation Building
University Park, PA 16802
Telephone Number: 925-337-5759
Advisor: Sayers John Miller, PhD, PT, ATC
Advisor Telephone Number: 814-865-6782
Subject’s Printed Name: _____________________________

We are asking you to be in a research study. This form gives you information about the research.

Whether or not you take part is up to you. You can choose not to take part. You can agree to take part and later change your mind. Your decision will not be held against you.

Please ask questions about anything that is unclear to you and take your time to make your choice.

1. Why is this research study being done?

We are asking you to be in this research because you have experience as a soccer player or dancer.

This research is being done to compare the dynamic balance in soccer players and dancers. Dynamic balance is the ability to maintain balance and movement coordination during activity. Approximately 30 people will take part in this research study at the Pennsylvania State University.

2. What will happen in this research study?

If you choose to participate in this research study, you will be asked to perform the following procedures:
Session 1:
a. Before testing begins, you will sign this written consent form.
b. You will begin the study with a light warm-up consisting of 5 minutes of self-paced walking on the treadmill to be ready for the test activities.
c. You will be asked to perform a single leg balance task called the Star Excursion Balance Test. For the Star Excursion Balance Test, you stand in place on one leg in the middle of the star and reach as far as possible with your other leg in eight (8) different directions: front, same-side diagonal front, same-side, same-side diagonal back, back, opposite-side diagonal back, opposite-side, opposite-side diagonal front. You will be given four (4) practice trials with thirty (30) seconds rest between trials. You will then complete three (3) trials where your maximum in each direction is marked and measured.

Figure 1. Star Excursion Balance Test

Session 2:
d. You will be asked to perform a modified Star Excursion Balance Test. You will complete the same pattern and skill as you performed in Session 1, but this time you will perform the task as quickly as possible. You will be given three (3) practice trials and three (3) official timed trials with thirty (30) seconds rest in between each trial, and three (3) minutes rest after completing the trials for this task.
e. You will be asked to perform a balance beam test. You will be asked to step onto a balance beam (10 cm wide, 10 cm high, and 500 cm in length). You will walk the length of the balance beam, hold at the end, with the toes of one foot touching the heel of your other foot, for three (3) seconds. You will then walk backwards to the first end of the beam, and step back onto the ground. You must complete this task as quickly as you can. If you fall off the balance beam, you must return to the last end of the beam you reached, and continue the test; the time will continue to run while you make another attempt to cross the beam. You will be given three (3) practice trials and three (3) official timed trials with thirty (30) seconds rest in between trials and three (3) minutes rest after completing the trials for this task.
You will be asked to perform the Step and Balance Test. Starting in the center box (X) you will leap to each of the numbered boxes in a predetermined pattern (Figure 1). You will then leap back to the center box and maintain stable balance for two seconds before leaping to the next box. Each trial will consist of 20 leaps. You will be given three (3) practice trials and three (3) official timed trials with thirty (30) seconds rest between trials and three (3) minutes rest after completing the trials for this task.

**Figure 2. Step and Balance Test – Right and Left Foot**

Tests will be performed in a randomly assigned order.

3. **What are the risks and possible discomforts from being in this research study?**

The discomforts and risks with participation in this type of research study are minimal. The tests used are within expected ranges for physically active people. To lessen the chance of injury, you will be shown how to properly perform every task in the experiment. We will take every possible step to prevent any risks.

4. **What are the possible benefits from being in this research study?**

The benefits to others include the potential to observe variances in dynamic balance capabilities in different athletic populations.

5. **What other options are available instead of being in this research study?**

You may decide not to participate in this research.
6. **How long will you take part in this research study?**

If you agree to take part, it will take you approximately forty-five (45) to sixty (60) minutes to complete each of two (2) visits in this study.

7. **How will your privacy and confidentiality be protected if you decide to take part in this research study?**

Efforts will be made to limit the use and sharing of your personal research information to people who have a need to review this information.
- A list that matches your name with your code number will be kept in a locked file cabinet or password protected file in the athletic training research laboratory, room
- Your research records will be labeled with your code number and will be kept in a locked file cabinet or password protected file in the athletic training research laboratory, room

In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

We will do our best to keep your participation in this research study confidential to the extent permitted by law. However, it is possible that other people may find out about your participation in this research study. For example, the following people/groups may check and copy records about this research.
- The Office for Human Research Protections in the U. S. Department of Health and Human Services
- The Institutional Review Board (a committee that reviews and approves research studies) and
- The Office for Research Protections.

Some of these records could contain information that personally identifies you. Reasonable efforts will be made to keep the personal information in your research record private. However, absolute confidentiality cannot be guaranteed.

8. **What are the costs of taking part in this research study?**

8a. **What will you have to pay for if you take part in this research study?**

There are no costs associated with participating in this study.

8b. **What happens if you are injured as a result of taking part in this research study?**

In the unlikely event you become injured as a result of your participation in this study, medical care is available. It is the policy of this institution to provide neither
financial compensation nor free medical treatment for research-related injury. By
signing this document, you are not waiving any rights that you have against The
Pennsylvania State University for injury resulting from negligence of the University or
its investigators.

11. What are your rights if you take part in this research study?

Taking part in this research study is voluntary.
- You do not have to be in this research.
- If you choose to be in this research, you have the right to stop at any time.
- If you decide not to be in this research or if you decide to stop at a later date,
there will be no penalty or loss of benefits to which you are entitled.

12. If you have questions or concerns about this research study, whom should you
call?

Please call the head of the research study (principal investigator), Amy Dykes at
(925)337-5759 if you:
- Have questions, complaints or concerns about the research.
- Believe you may have been harmed by being in the research study.

You may also contact the Office for Research Protections at (814) 865-1775,
ORProtections@psu.edu if you:
- Have questions regarding your rights as a person in a research study.
- Have concerns or general questions about the research.
- You may also call this number if you cannot reach the research team or wish to
talk to someone else about any concerns related to the research.

INFORMED CONSENT TO TAKE PART IN RESEARCH

Signature of Person Obtaining Informed Consent

Your signature below means that you have explained the research to the subject or
subject representative and have answered any questions he/she has about the
research.

______________________________
Signature of person who explained this research

________
Date

______________________________
Printed Name

(Only approved investigators for this research may explain the research and obtain informed
consent.)

Signature of Person Giving Informed Consent

Before making the decision about being in this research you should have:
- Discussed this research study with an investigator,
- Read the information in this form, and
- Had the opportunity to ask any questions you may have.
Your signature below means that you have received this information, have asked the
questions you currently have about the research and those questions have been
answered. You will receive a copy of the signed and dated form to keep for future
reference.

**Signature of Subject**

By signing this consent form, you indicate that you voluntarily choose to be in this research
and agree to allow your information to be used and shared as described above.

___________________________  ______________  ___________________
Signature of Subject                Date             Printed Name


Appendix E: Data Collection Form

Height: ________________ Age: ________________

Weight: ________________ Dominant Limb: ________________

Sport: ________________ Leg Length: ________________

Task Order: ________________ ________________ ________________ ________________

SEBT Distances:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>AL</th>
<th>L</th>
<th>PL</th>
<th>P</th>
<th>PM</th>
<th>M</th>
<th>AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90% Avg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150% Avg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BBT Trial times:

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>Errors Forward</th>
<th>Errors Backward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
mSEBT Trial times & errors:

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Errors</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* "X" denotes error

SBT Trial times & errors: (Right Leg)

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Errors</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

"I" denotes error
### mSEBT Trial times & errors:

<table>
<thead>
<tr>
<th>Trial</th>
<th>Time</th>
<th>Total Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* "X" denotes error

### SBT Trial times & errors: (Left Leg)

<table>
<thead>
<tr>
<th>Trial</th>
<th>Time</th>
<th>Total Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“I” denotes error
References


Amy Dykes, ATC, NASM-CES, NASM-PES

Education

Pennsylvania State University; University Park, PA August, 2015
M.S., Kinesiology
Azusa Pacific University; Azusa, CA May, 2013
B.A., Athletic Training

Other Skills and Positions

- BOC Certified Athletic Trainer (ATC) – May 2013
- NASM Corrective Exercise Specialist (CES) – June 2012
- NASM Performance Enhancement Specialist (PES) – July 2013
- American Red Cross CPR and AED for the Professional Rescuer
- Vice President for Azusa Pacific University’s Athletic training Student Organization
  - Encouraging involvement in philanthropic community events
  - Organizing and coordinating student attendance at 2013 NATA convention
  - Recipient of Bill Ito Scholarship Award