Reliability of the Single Leg Romberg Stance Test Compared to the Balance Error Scoring System

A THESIS
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Master of Science

by
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Proprioception is the ability to sense position, orientation, and movement of the body and its parts.\textsuperscript{1,2} Mechanical receptors scattered throughout the body are used to determine proprioception and are primarily found in the musculotendinous junction that consists of muscles, tendons, ligaments, and joint capsules.\textsuperscript{3}

Somatosensory, visual, and vestibular systems work together to sense body position in relation to gravity and the external environment.\textsuperscript{3} The organs of the somatosensory system detect the sensations of touch, pressure, vibration, and the sense of position. The somatosensory tactile organs along with the Golgi tendons and muscle spindles work together to provide the central nervous system (CNS) with information regarding joint position.

There are many internal and external factors that can influence proprioception. Joint stability is an internal factor that can have a negative effect on proprioception. Stabilizers include static and dynamic which work together to help the body to maintain joint stability.\textsuperscript{4} Static stabilizers includes ligaments, joint capsules, cartilage, friction, and bony geometry.\textsuperscript{5} Dynamic stabilizers includes muscles and their tendons that cross that specific joint.\textsuperscript{5}
Mild head injury (MHI) is an external factor that can have a negative effect on balance. MHI is a cranial trauma that results in alteration of mental status, disturbance of vision, and equilibrium due to brain stem involvement. Diagnosis of the severity of MHI is difficult. Many researchers have examined the use of balance tests to measure the severity of head trauma.

Over the past decade many new balance testing methods and instruments have been used to measure balance impairment after a MHI. The two most commonly used tests that require no special instruments are the modified Romberg test and the Balance Error Scoring System (BESS). MHI can decrease postural stability and a studied showed postural stability decreased one day after injury. Based on these findings, the BESS has been shown to be a practical, valid, and cost effective method of objectively assessing postural stability in athletes suffering from a concussion.

Clinicians, certified athletic trainers, and team physicians commonly use the Romberg test to measure balance after a suspected MHI. The use of the modified Romberg test may be questionable for two reasons. First, the modified Romberg test lacks similarity to activities of daily living and skills used in athletes. Second, little research is
available that stated the reliability of the modified Romberg test in the young healthy population.

Variations of the Romberg test that could be best used to assess a MHI have been reviewed. Statistical analysis revealed that the original Romberg test might not be sensitive enough to detect deficits in postural stability following MHI. Riemann suggested that if the certified athletic trainer decided to use the Romberg test to evaluate balance then the single leg Romberg stance test and the tandem stance test are recommended.

The single leg Romberg stance test, however, is one of the most used variations of the Romberg test in the clinical setting. A study performed on 45 healthy elderly women compared the sharpened Romberg Test (SR), also known as the tandem stance, and the one-legged stance test (OLST) to two other quick quantitative tests. Results showed that even though the SR and OLST are quick, simple, and inexpensive, they are poorly representative of motor tasks in everyday life in this population. Interclass Correlation Coefficient interval ranged from $r=0.40-0.66$. Research suggests that the tandem stance test is a better measurement of balance for an on-the-field assessment. Athletes can maintain their balance better if the base of support is wider. However, normal
activities of daily living and sports activities do not always have both feet on the ground. Activities such as walking down the stairs involve one leg. Research performed by Riemann suggests that the single leg Romberg stance test may be more appropriate to measure balance, because it is more suitable for activities of daily living.3

The Balance Error Scoring System (BESS) is a clinical test that is recommended by some researchers over the single leg Romberg stance test.3,4,10 BESS serves as a reliable clinical evaluation measure.9 According to research performed by Hoffman, high intraclass correlation coefficients for both intertester (.78 to .96) and intratester (.87 to .98) were found.9 A study by Guskiewicz showed that test-retest reliability was moderate (r=.673).6 Hunt (2005) conducted a study determining the percent variance associated with each measure of the BESS. The results showed a moderately high correlation coefficient of 0.706. These results mean that the BESS test is a reliable measure of balance.11

A significant learning effect has been represented for the BESS system effects on the BESS system with long-term retention occurring for single leg/ground, single leg/box, and tandem/box conditions, but at different times in the test sequence for each condition. Learning occurred
between the first two sessions for the two tremor box conditions, and by day three for the single-leg conditions. These findings suggest that balance can be learned, and that testing should be done in random order.\textsuperscript{12}

Research has been performed to examine the effects of fatigue on balance. Fatigued groups had significantly more total errors on the posttest then on the pretest.\textsuperscript{6} Fatigue affected performance on the tandem conditions more than on the double and single-leg conditions. Postural stability was also decreased, as a result of fatigue, as measured by the BESS total error scores. Effects of fatigue appeared to be condition specific, concurring with previously reported findings that showed fatigue had more effect with the tandem stance on the foam pad.\textsuperscript{6}

Research has also determined how long it may take to recover after performing the BESS test.\textsuperscript{13} Results showed that exertion can harmfully affect balance. These findings suggested that after exertion exercises, fatigue could result in false-positive findings, such as higher error points, while performing the BESS test.\textsuperscript{13}

The purpose of this study was to determine the reliability of the single leg Romberg stance test and compare it to the BESS to determine which test was more reliable for a quick field assessment for balance. The
questions that would be answered in this study are: (1) Will an inverse relationship be found between the time (seconds) on the single leg Romberg stance test and the error scores (points) for the BESS test, and (2) What is the reliability of the single leg Romberg stance test in a young, healthy population?
METHODS

Research Design

To examine the relationship of the Romberg and the BESS scores this study used a Pearson product moment correlation design. The variables are the BESS error score measured in points, and the single leg Romberg stance test score measured in seconds. A test-retest design will be used to evaluate the reliability of the Romberg scores. Testing was done in one day; half of the subjects performing the BESS test first, while the other half performed the single leg Romberg stance test first. Findings may have been limited due to the college age students used as subjects.

Subjects

Twenty-one (N=21) healthy college aged students from California University of Pennsylvania participated in this study. Undergraduate athletic training students and graduate athletic training students were asked to volunteer for this study after the researcher explained the concept of the study to the participant by oral and written
documentation. Any subject who had suffered from visual, vestibular, or balance disorders, lower extremity injury, and/or concussion within the last six months was excluded from this study as these conditions may have interfered with accurate balance assessment. The California University of Pennsylvania Institutional Review Board (IRB) approved the study. All subjects read and signed the informed consent form (Appendix C1) prior to participation in this study.

Instruments

A demographic sheet (Appendix C2), the single leg Romberg stance test, and the Balance Error Scoring System (BESS) (Appendix C3) were used in this study. A stopwatch was used to measure the time during performance of the Romberg. The Romberg and BESS tests are quantifiable clinical tests that have been developed to evaluate impairments of balance and coordination.\(^3,12\)

**BESS**

When performing the BESS test, standard procedures were followed to reduce subject risk. Subjects were given one practice trial before each test to reduce the chance of a learning effect. The BESS test was performed on three
different stances (double, single, tandem) on two different surfaces (flat surface, and medium density foam pad). Each stance was completed once on each surface for a total of six tests. Progression went from easiest (double-flat) to hardest (tandem-foam). Subjects were tested with their eyes closed, and were asked to assume the required testing stance by placing their hands on their iliac crest during the 20 seconds testing time.³,¹²

The single leg test of the BESS was performed on the non-dominant leg. During the single leg test, subjects were asked to maintain the non-weight bearing leg in approximately 20–30° of hip flexion, and 40–50° of knee flexion.¹² During the tandem stance the non-dominant leg was placed in front of the dominant leg.¹²

Upon losing their balance, subjects were asked to make the necessary adjustments and return to the testing position as quickly as possible, adding one error point for each error committed. Errors include the following: moving hands off of iliac crest, opening the eyes, stepping, stumbling, or falling, moving the hip and/or knee out of testing range, lifting the forefoot and/or heel, and remaining out of the testing position for more than 5 seconds (Appendix C4).³,¹² Scoring was done by adding all of
the errors scores from all six tests together for a total score. Higher scores represented poorer balance.

**Single leg Romberg stance test**

The single leg Romberg stance test is a quick field balance test commonly used in athletic training. While performing the single leg Romberg stance test, standard procedures were followed to reduce the chance of injury. Subjects were tested on a firm surface to eliminate the effects of weather and varying surface conditions that may be encountered during real life testing. Subjects were tested on their non-dominant leg with their eyes closed. Subjects maintained the testing position by keeping their hands on their iliac crest, eyes closed, and upon the command of go lifted their non-dominant leg up to approximately 20° of knee flexion. Performance was measured by the amount of time it took the subject to touch the non-weight bearing leg to the ground, or until they reach the 60 second time limit. A stop watch was used to measure time.

**Procedures**

The California University of Pennsylvania Institutional Review Board (IRB) (Appendix C5) approved the
study. Healthy twenty one (n=21) college aged students at California University of Pennsylvania were asked to volunteer to participate in this study. Undergraduate and graduate athletic training students were asked to participate in this study after the researcher explained the concepts of the study during a brief meeting. After agreeing to participate they read and signed the informed consent form.

Before testing began a preliminary investigation was performed. Two subjects were tested under the same conditions in the same manner with the procedures of this study. This pilot research assisted the researcher to become familiar with the scoring procedures of the BESS test, and determine the amount of time that was needed to test subjects.

In an effort to decrease the potential learning effect, tests were performed in random order. Half of the subjects performed the single leg Romberg stance test first and the BESS test second, while the other half performed the BESS test first and the single leg Romberg stance test second. The researcher recorded the scores on the single leg Romberg stance test and BESS test (Appendix C6).

Qualified subjects completed both tests on the same day. Subjects signed up for a 25-minute time slots. All
testing procedures were completed in the athletic training room at California University of Pennsylvania. They were performed in the same location for each subject. To determine the order of testing, subjects selected a sheet of paper from a bag. Each sheet contained a different testing order, either BESS first or Romberg first. If the sheet of paper had the number one written on it the single leg Romberg stance test was performed first, and the BESS was performed second. If the sheet of paper had a number two written on it the BESS test was performed first, and the single leg Romberg was performed second. The testing procedures were read again at the beginning of each test (Appendix C7). The visual field was controlled by having the subject face a blank wall and the researcher stand behind the subject. Researcher position also helped to reduce risk of injury to the subject.

The BESS test was performed on two surfaces. One was the flat, dry, carpeted floor, and the second surface was a medium-density foam pad. Both tests were initiated from the command to begin (ready, go) and ended with the command of stop. Subjects were given a one-minute rest in between each test to reduce the effects of fatigue. Subjects were given one practice trial for each test to familiar with the testing procedures and reduce possible learning effects.
Single leg Romberg stance test

Subjects were asked to stand barefoot on their non-dominant foot. To determine their dominant foot, the researcher asked the subjects that if they were to kick a soccer ball what foot would they use. The foot that they had chosen to use was their dominant foot. Subjects were tested on firm surface. The subjects placed their hands on their iliac crest and closed their eyes upon command from the researcher. Upon closing their eyes testing began. The time that it took them to touch the non-weight bearing leg to the ground was recorded up to one minute. Once the non-weight bearing leg touches the ground, or if they maintained balance for one minute the test was complete.

BESS-Double Leg Stance

The subjects performed this test on both surfaces (flat floor, medium-density foam) barefoot for 20 seconds. The subjects were asked to close their eyes, place their hands on their iliac crest, place feet together, and stand still. Subjects were given one practice trial to become familiar with the test, and to reduce any possible learning effects. Each time an error was performed a point was
given. Error scores were added up after the 20 seconds were completed.

**BESS-Single Leg Stance**

The subjects performed this test on both surfaces barefoot on their non-dominant leg. To determine their non-dominant foot, the researcher asked the subjects what foot would they use to kick a soccer ball. The foot that they had chosen was determined to be their dominant foot. Their non-weight bearing leg was placed approximately 20-30° of hip flexion and 40-50° of knee flexion. Subjects were asked to place their hands on their iliac crest, close their eyes, and place their hip and knee in the recommended angles. Subjects were given one practice trial to become familiar with the test, and to reduce learning effects. Each time an error occurred a point was given. After 20 seconds the error scores were added together.

**BESS-Tandem stance**

Subjects were asked to place their non-dominant leg behind their dominant leg and were asked to stand in a heel-to-toe manner. The subjects were then asked to close their eyes, and place their hands on their iliac crest. Subjects were given one practice trial to become familiar
with the test, and to reduce any possible learning effects. The subjects were tested on both surfaces, barefoot for 20 seconds. After 20 seconds the error scores were added together.

Hypothesis

The following hypothesis was tested in this study:

There will be an inverse relationship found between the single leg Romberg stance test time (seconds) and the BESS error scores (points). As time on the single leg Romberg stance test decreases, the errors scores committed on the BESS should increase, indicating poor balance.

Data Analysis

A Pearson Product Moment Correlation was performed on the single leg Romberg stance test and BESS scores, and compared the two balance tests to age, height, weight. The data analysis was performed using the SPSS 14.0 statistical software package at an alpha level of $P \leq 0.05$. A test-retest design was used to evaluate the reliability of the Romberg scores.
Results

The primary purpose of this study was to compare the single leg Romberg stance test to the Balance Error Scoring System in an effort to determine if the Romberg test is a valid measure of balance. This study compared the single leg Romberg stance test to the sum of the BESS scores. In addition, this study determined the reliability of the single leg Romberg stance test in the college age population. The relationship between the sum of the BESS scores and each individual test in the BESS was also examined. This study determined if there was a relationship between performance in the single leg Romberg stance test and the BESS test to age, height, and weight. This was done to determine if these factors played a role in the subject’s ability to maintain balance.

Demographic Data

This study involved collecting data from 21 volunteers (16 females, 5 males), ages ranging from 18 to 27. The mean height of the subjects was 65.38cm, with a mean weight of 158.02 pounds. Mean age of the subjects was 23 years. The means and standard deviations for the single leg
Romberg stance test, individual BESS subtests and the overall BESS score can be found in Table 1.

Table 1. Means and Standard Deviations for all Seven Tests

<table>
<thead>
<tr>
<th>Balance Tests</th>
<th>Means</th>
<th>Standard Deviations</th>
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</thead>
<tbody>
<tr>
<td>Romberg</td>
<td>46.33 (Sec)</td>
<td>18.02</td>
</tr>
<tr>
<td>* BESS Firm Double leg</td>
<td>0.00 (Errors)</td>
<td>0.00</td>
</tr>
<tr>
<td>BESS Firm Single leg</td>
<td>2.76 (Errors)</td>
<td>2.189</td>
</tr>
<tr>
<td>BESS Firm Tandem Stance</td>
<td>0.81 (Errors)</td>
<td>1.632</td>
</tr>
<tr>
<td>BESS Foam Double leg</td>
<td>0.19 (Errors)</td>
<td>0.680</td>
</tr>
<tr>
<td>BESS Foam Single leg</td>
<td>6.57 (Errors)</td>
<td>2.959</td>
</tr>
<tr>
<td>BESS Foam Tandem stance</td>
<td>4.57 (Errors)</td>
<td>3.487</td>
</tr>
<tr>
<td>**BESS Sum</td>
<td>14.90 (Errors)</td>
<td>7.899</td>
</tr>
</tbody>
</table>

* BESS firm double leg score recorded zero because no subject performed any errors.
**BESS sum score is the total score from all six BESS tests.
Hypothesis Testing

The hypothesis of this study stated that there will be an inverse relationship found between the single leg Romberg stance test time (seconds) and the BESS error scores (points). As time on the single leg Romberg stance test decreases, the errors, measured in points, committed on the BESS should increase, indicating poor balance. An inverse of negative correlation would be expected since someone skilled in balance would score high on the Romberg test and low on the BESS test.

Results confirmed the hypothesis and showed a significant high moderate correlation ($r_{(19)} = .759, P=0.01$), indicating a relationship between the two variables. Results can be found in Table 2.

Table 2. Pearson Correlation Coefficients between Single Leg Romberg and the BESS Tests

<table>
<thead>
<tr>
<th>BESS Test (Total error scores)</th>
<th>Romberg Test</th>
</tr>
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<tbody>
<tr>
<td>BESS Sum</td>
<td>-.759**</td>
</tr>
</tbody>
</table>

**Correlation is significant at the 0.01 level (2-tailed)**
Additional Findings

Intraclass Correlation Coefficient (ICC) for the single leg Romberg stance test was found at (r=.911) with a 95% confidence interval ranging from (.795-.963). The results indicate that if the subject scored high on the pre-test, they scored high on the post-test.

This study determined the intraclass correlation coefficient of the single leg Romberg stance test in the college-aged population. Twenty-one subjects (n=21) performed the single leg Romberg stance test twice (pre-post test). The mean time, measured in seconds, for the pre-test was 43.90+18.08. The mean time for the post-test was 46.33±18.02. The means and standard deviations can be found in Table 3.

<table>
<thead>
<tr>
<th>Balance Test</th>
<th>Means</th>
<th>Standard Deviations</th>
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</thead>
<tbody>
<tr>
<td>Pre Romberg</td>
<td>43.90</td>
<td>18.08</td>
</tr>
<tr>
<td>Post Romberg</td>
<td>46.33</td>
<td>18.02</td>
</tr>
</tbody>
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A Pearson Product Moment Correlation Coefficient was performed to see if a relationship existed between the sum of the BESS error scores and each subtest of the BESS, and
to determine if age, height, and weight can determine how well a person can balance.

A positive correlation was found between the tandem stance on the foam pad and the sum of the BESS \((r(19).837, P=0.01)\). When the sum of the BESS was compared to the single leg stance on the firm surface, a positive correlation coefficient was found \((r(19).829, P=0.01)\), indicating that these two subtests of the BESS can predict the outcome score on the BESS test in this population. Results can be found in Table 4.

Table 4. Pearson Correlation Coefficients Between the Sum of the BESS Scores and the Subtest of the BESS Test

<table>
<thead>
<tr>
<th>BESS Subtest</th>
<th>Sum of the BESS</th>
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<tbody>
<tr>
<td>BESS Firm double leg</td>
<td>0.00</td>
</tr>
<tr>
<td>BESS Firm single leg</td>
<td>0.829**</td>
</tr>
<tr>
<td>BESS Firm tandem stance</td>
<td>0.619**</td>
</tr>
<tr>
<td>BESS Foam double leg</td>
<td>-0.006</td>
</tr>
<tr>
<td>BESS Foam single leg</td>
<td>0.730**</td>
</tr>
<tr>
<td>BESS Foam tandem stance</td>
<td>0.837**</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed)
0 Cannot be computed because at least one of the variables is constant.
Age, height, and weight were not significantly correlated with one another, and therefore cannot be used to determine balance in this population.
DISCUSSION

One of the primary concerns facing sports medicine professionals in assessing balance in an athlete is the efficacy of the test they are using. For years sports medicine professionals have used the single leg Romberg stance test to assess an athlete’s balance. More recently the BESS test was developed as a clinical assessment tool to determine the balance status of an athlete. Questions remain as to which test is best to use in an athletic population.

BESS is a newer clinical test that is recommended by some clinicians over the standard Romberg test.\textsuperscript{1,20,23} BESS uses three different stances (double, single, tandem) that are completed twice, once while on a firm surface and once while on a 10-cm thick piece of medium-density foam.\textsuperscript{21(p162)} Subjects are instructed to assume the required stance by placing their hands on their iliac crest, and close their eyes for 20 seconds.\textsuperscript{1,14,21} Due to the various trials, the BESS takes longer to perform than the Romberg.

Clinicians commonly use the Romberg test as the main field test to examine postural stability.\textsuperscript{23,24} Normally, athletes can maintain balance by standing motionless during the single leg stance. The test is performed by having the
client stand on their non-dominate leg, and bend their dominate leg approximately 20°. A positive test is when the athlete begins to sway, cannot keep their eyes closed, or obviously lose their balance.1,27 The patient should be able to stand motionless for approximately 30 seconds without touching the non-weight bearing foot to the ground.2 The test is stopped once the non-weight bearing leg touches the ground, or until balance is maintained to the end of the time limit.

The single leg Romberg stance test is one of the most used variations of the Romberg test in a clinical setting. Prior to the current study, one other study was found in the literature to have tested the reliability of the single leg Romberg stance test. The study was performed on forty-five healthy elderly women comparing the sharpened Romberg Test (SR) and the one-legged stance test (OLST) to two other quick quantitative tests. Results showed that even though the SR and OLST are quick, simple, and inexpensive, they are poorly representative of motor tasks in everyday life. Reliability value was found for the SR test to be at 0.40-0.66. The study suggested examining a younger population.8,9

The current study determined the intraclass correlation coefficient of the single leg Romberg stance
test in the college age population. Test-retest reliability measures temporal stability, and tells the researcher whether or not the instrument is consistent over time and/or over multiple administrations. Subjects performed the single leg Romberg test twice (pre and post). Time was recorded in seconds. The test is completed once the non-weight bearing leg touched the ground, or until balance was maintained to the end of the 60-second time limit.

The results of this study indicate that if the subject scored high, indicating good balance, during the pre-test they also recorded a high time during the post-test. The reliability of the single leg Romberg stance test in the college age population is a reliable measure of balance.

Previously studies have shown that BESS serves as a reliable clinical evaluation measure. High intraclass correlation coefficients for both intertester (.78 to .96) and intratester (.87 to .98) were found when examining evaluation measures between Certified Athletic Trainers (ATC) and Athletic Training Students (ATS). Test-retest reliability was found moderate ($r=.673$). When examining the percent variance an intraclass correlation coefficient ($R=.604$) for all six trials of the BESS test was found.⁹
Hypothesis of the current study examined if an inverse relationship between the time on the single leg Romberg stance test and the error scores on the BESS test was present. The inverse relationship suggests that, as time on the Romberg goes up error scores on the BESS test should go down, indicating good balance. If an inverse relationship exists there is a negative score.

This study determined that a moderate correlation was found between the two balance tests. This suggests that when assessing balance on an athlete the Romberg could be used as an on-the-field assessment of balance. It is a quick and simple way to measure balance and it does not require equipment. The BESS may be better suited for use in a clinical setting, because it is more time consuming and requires equipment, but may be a more valid measure of balance.

A study performed by Riemann investigated several variations of the Romberg test. Three different stances (double, single, and tandem) on two different surfaces (firm and foam) were investigated. Riemann found a significant difference on day one on the single leg stance and the tandem stances. This study also found a strong correlation when it compared these two subtests of the BESS to the overall sum of the BESS error scores. The present
study along with the study performed by Riemann, suggests that these two tests should be considered when performing a sideline or clinical balance assessment.\textsuperscript{25}

Additionally this study examined the relationship between the scores of the balance tests to age, height, and weight. A previous study examined the balance ability in the elderly population. Subjects had a difficult time maintaining balance for the 30-second time limit. The study suggested that results may vary if a younger, healthier, population was used as subjects.\textsuperscript{8} For the current study, time limit was set at 60-seconds for the Romberg. A weak correlation was found, indicating that age, height, and weight cannot be used to determine balance.

Conclusion

This study compared the single leg Romberg stance test to the BESS test to determine if the Romberg was a valid and reliable measure of balance. The results showed that the single leg Romberg can be used as a quick on-the-field assessment of balance. When performing the BESS test the tandem stance on the foam pad and the single leg stance on the firm surface can predict the outcome score on the BESS
test in this population. Age, height, and weight cannot be used to determine balance.

Recommendations

Future studies should be directed in testing subjects on the single leg Romberg stance test and the BESS test on separate days. Since the single leg Romberg stance test and the best test both use the non-dominant leg when standing, these two tests should be done on separate days to prevent fatigue. The subjects for this study performed one practice trial with a minute rest in between testing. Rest periods may need to be increased to help prevent fatigue, or no practice trials should be given to make the test as close to an on-the-field assessment as possible. Also, a wider age population should be used to determine if younger people have better balance, and if age could be used to determine a person’s balance ability.

The findings of this study can help improve the profession of athletic training. The Romberg test is a, quick, inexpensive way to measure postural balance in athletes. The BESS test requires equipment, but may be more valid in a clinical setting. During lower extremity rehab, the Romberg may be used to improve balance and joint
stability. Athletes can use both balance tests to help improve balance in the off-season. The current study and the research of others will aid sports medicine professionals in devising an effective, and objective testing battery for assessing postural control.
REFERENCES


APPENDICIES
APPENDIX A

Review of the Literature
The Balance Error Scoring System (BESS) is recommended over the standard Romberg test when assessing athletes that have sustained a mild head injury (MHI) or have experienced a balance disorder.¹ However, most certified athletic trainers perform the modified Romberg test over the BESS for balance assessment. The purpose of this literature review is to discuss: 1) the role of proprioception, 2) balance and postural stability, and 3) validity and reliability of balance tests, specifically the Romberg and BESS tests.

The Role of Proprioception

Proprioception is a sense that provides feedback of the body status internally. Proprioception is defined as the body’s ability to transmit a sense of positions, analyze that information, and react to the situation with the proper movement.²,³ Other definitions of proprioception includes the combination of total posture (postural equilibrium) and segment posture (joint stability), as well as initiation of several conscious peripheral sensations.³ Put simply, it is the sense that indicates whether the body
is moving with required effort, and where the various parts of the body are located in relation to each other.

**Proprioceptive Feedback**

Proprioceptive feedback is a continual process that gets information from the afferent pathways that carry proprioception information.³,⁴ Proprioceptive feedback relies on sensory and motor control that sends and receives information from the peripheral receptors. Such mechanical receptors are located in the skin, muscles, tendons, and joints, and sense gravity, joint positions, and movement.

**Somatosensory System**

The organs of the somatosensory system detect the sensations of touch, pressure, vibration, and the sense of position. Generally the sensors of touch, pressure, and vibration are referred to as tactile senses. These organs are sensitive to pressure and touch. The tactile organs include pacinian corpuscles, free nerve endings, Meissner’s corpuscles, and Ruffini endings.

The Pacinian Corpuscles are small, ellipsoidal bodies located close to the Golgi tendon organs and embedded in a single, non-myelinated nerve fiber.⁷ These sensory receptors are sensitive to quick movement and deep
pressure. Compression of the onion like capsule by a mechanical stimulus transmits pressure to the sensory nerve ending within its core.\textsuperscript{7} This produces a change in the electrical potential of the sensory nerve ending. If this generator potential reaches sufficient magnitude, a sensory signal propagates down the myelinated axon that leaves the corpuscle.\textsuperscript{7}

Pacinian corpuscles are classified as fast-adapting mechanical receptors because they discharge a few impulses at the onset of a steady stimulus and then remain electrically silent or may discharge a second volley of impulses when the stimulus ceases.\textsuperscript{7} Therefore, they detect changes in movement or pressure, rather than the magnitude of movement or the quantity of pressure applied.\textsuperscript{7}

Ruffini endings are one of the four main cutaneous mechanoreceptors. Ruffini’s endings respond to tension and stretch in the skin. They are found deep in the dermis of the skin, and have a thin capsule surrounding a fluid-filled cavity. This cavity contains a collagen mesh that penetrates the capsule to anchor it to the surrounding tissue. The nerve ending loses its myelination as it enters the capsule, and its branches weave around the collagen fibers and respond to movements of the surrounding tissue.
The Ruffini’s endings are incompletely (or slowly) adapting.  

Meissner's corpuscles are touch and superficial pressure receptors that are located on the epidermis-dermis boundary, especially on the fingertips, palm, sole of the foot and nipple. They are oval in shape and consist of many stacked, flattened Schwann cells. The nerve fibers enter the deep end of the corpuscle. Meissner's corpuscles are completely (or rapidly) adapting.  

Free nerve endings work as continuous receptors and are more sensitive to pressure. They are widely distributed throughout the body, and are found as branches of non-myelinated, or lightly myelinated fibers grouped in bundles beneath the epithelium. As they penetrate the epithelium, they lose their myelin, and branch among the epithelial cells. Branches of one nerve may cover a wide area and overlap the territories of other nerves. The free nerve endings detect pain, touch, pressure and temperature, and are associated with C fibers.  

Two special somatosensory organs located throughout the muscles and tendons, pass on information regarding muscle tension, and the rate of change in length or tension. These organs send inputs to the central nervous
system (CNS), which assist in determining joint position. These two organs are Golgi tendons and muscle spindles.\textsuperscript{7}

Golgi tendon organs (GTO) are located in tendons close to the musculotendinous junction and will respond to a sudden increase in muscular tension and cause a protective relaxation, or inhibitory, response.\textsuperscript{6,7} Each GTO inserts into a small bundle of muscle tendon fibers that are attached to a very low threshold and high dynamic sensitivity exhibited by the sensory endings. Ultimately, the GTO protects the muscle and its connective tissue harness from injury due to excessive load.\textsuperscript{7}

Muscle spindles are located within the musculotendinous junctions. Muscle spindles contribute to proprioception (sense of position) and possibly kinesthesia (sense of movement).\textsuperscript{7} Muscle spindles are found within the belly of the muscles and run parallel with the main muscle fibers. Muscle spindles are responsible for information regarding changes in muscle length and the rate of the change.

Muscle spindles have sensory nerve terminals whose discharged rate increases as the sensory ending is stretched. This nerve terminal is known as the annulospiral ending, so named because it is composed of a set of rings in a spiral configuration.\textsuperscript{7} These terminals
are wrapped around specialized muscle fibers that belong to the muscle spindle (the intrafusal fibers) and are separated from the fibers that make up the bulk of the muscle (extrafusal fibers). 7

Along with the joint information, information from the spinal cord plays an integral role in motor control. From the spinal cord arise direct motor responses to peripheral sensory information and elementary patterns of motor coordination. Most of the information terminates upon the interneuron's that are located throughout the spinal cord’s gray matter. 8

The information from the mechanical receptors and spinal cord travels to the brain stem where it is received by one of the two pathways. The medial pathway influences the motor neuron that innervates the axial and proximal muscles. 6 The lateral pathway includes the muscles that help with postural control. 5 Overall, the sensory motor system encompasses all of the sensory, motor, and central integration and processing components involved with maintaining joint homeostasis during body movement. 3

Movements necessary to maintain balance involve the joints and muscles of the entire kinetic chain. The actions that represent neuromuscular control are aimed at preparing, maintaining, and restoring stability of the
whole kinetic chain.\textsuperscript{8} Neuromuscular control is defined by Reimann\textsuperscript{5} as the unconscious activation of dynamic restraints occurring in preparation for and in the response of joint motion and loading for the purpose of maintaining the alignment. Dynamic stability is when static balance is required to maintain the center of gravity (COG) over a base of support.\textsuperscript{9} The base of support is defined as the area contained within the support surface (two feet).\textsuperscript{6} If there is an injury to a segment of the body, neuromuscular control is inhibited and must be relearned.

**Maintaining Joint Stability**

Static and dynamic stability helps the body to maintain joint stability.\textsuperscript{10} Static stability includes ligaments, joint capsules, cartilage, friction, and bony geometry.\textsuperscript{8} To measure static stability one measures through joint stress testing. Dynamic stability arises from feed forward and feedback neuromotor control over the skeletal muscles that cross the joint. Feed forward controls have been described as anticipatory actions occurring before the sensory detection of a homeostatic disruption.\textsuperscript{8} These two components help the body to maintain its COG.

To truly relearn proprioception, clinicians have the subject stand on one leg and close their eyes. Taking away
vision helps the motor control to adapt to changes that occur suddenly to the body. This adaptation makes the adjustment process become quicker and more accurate. Before and during the motor command, the motor system must consider the current and changing position of the joints involved. When multiple joints move at once it is an overlapping sequence.

The Effects of Proprioception on Balance

Balance is defined as the body’s ability to maintain equilibrium by controlling the body’s center of gravity over its base of support. The ability of the body to maintain its COG well with minimal deviation requires the coordination activation of joints, muscles, visual, and vestibular receptors. The maximal sway angle of COG depends on the limits of stability that is considered to generally be 16° in all directions.

Along with the somatosensory system, sensory information gathered from the vestibular and visual sensors allows the body to sense the body’s COG in relation to both gravity and base of support. None of these three systems directly measures COG position. However, each provides unique perspectives of sensory information.
The ear is composed of three different sections. The design of the ear permits it to focus acoustical energy and convert it into an electrical signal that can be interpreted by the brain. The ear also functions to maintain balance. There are two types of vestibular sensors for conveying equilibrium input: the three semicircular canals and the two-otolith organs.6

Within the inner ear, the mechanical vibrations caused by sound waves are encoded into electrical impulses to be interrupted by the brain. The portion of the vestibular system that relies on balance is located adjacent to the auditory portion with in the bony labyrinth of the temporal bone.6,14 Acoustic signals are passed along the cochlea, a bony structure that moves up and down in response to these signals. This movement is detected by fine hair cells and subsequently translated into electrical impulses by the vestibulochlear nerve.

The semicircular canals are filled with fluid, and as the head moves, the fluid in the canals shifts. The feedback from this movement is provided to the brain, assisting in maintaining balance and an upright posture of the head and body.6,14
The otoliths consist of the utricle and the saccule. Both of these organs sense changes in orientation relative to gravity. The utricle senses motion in the horizontal plane and the saccule senses motion in the sagittal plane. The transduction regions of the utricle and the saccule are the maculae. The maculae of both organs contain hairs that are arranged in a way that allow them to only sense motions in the horizontal and sagittal planes. These hair cells are connected to the vestibulochlear nerve.

**Hip, Knee, and Ankle Strategies**

An activity of the body involves both feed forwarding and feedback mechanisms. These specific strategies are taken to ensure the maintenance of postural control. Postural control is a continuous process, and it requires the sensory detection of body and segment motion and position and the integration and processing of the information within the central nervous system into efferent commands.

Single leg stances occur frequently within many activities of daily living. Postural stability increases during single leg stance most likely as a result of the required reorganization of the center of gravity over a short and narrow base of support. The body does not work
move as a rigid segment, but rather as a multi-link structure. Each joint in the kinetic chain supports and moves with the joints above and below it.

Riemann\textsuperscript{18} looked at the hip, knee, and ankle involvement during eyes open and eyes closed during single leg stance. The results showed that there is very little corrective action between the ankle and the trunk during eyes open stance. However, when the eyes were closed corrective measures between the ankle, knee, and hip were high. The ankle joint showed the most corrective measures during the eyes open/eyes closed compared to the joints.\textsuperscript{18} As the task became harder (on form surface) there was an increased reliance on the proximal joints.\textsuperscript{18,19} During the eyes closed test, the hip became the second largest source of corrective action, whereas both the hip and knee contributed during eyes closed. The trunk played no part in corrective measures.\textsuperscript{18} These results show the importance of the ankle joint for the single leg stabilization on different surfaces. Proximal joints play a great role in stability under more challenging conditions.\textsuperscript{18,19}

Literature suggests that the hip is a more important component of postural stability in the sagittal plane.\textsuperscript{19} Blackburn\textsuperscript{19} conducted a study to differentiate hip and trunk motion during double leg stance.\textsuperscript{19} The results revealed no
significant differences in trunk and hip motion during the double leg stance. These results suggest that motion of the trunk and hip on postural control happens during all planes of motion.\textsuperscript{19} Hip and trunk motion remains similar until vision is taken away. As Riemann (2003) showed in his study the hip became the second largest source of corrective action.\textsuperscript{18} Both of these studies suggest that most corrective measures for balance happen at the ankle and the hip.

**Mild Head Injury**

Deciding when athletes can safely return to competition following a mild head injury (MHI) is one of the greatest challenges facing certified athletic trainers and team physicians.\textsuperscript{15,16} Mild head injury is cranial trauma resulting in alteration of mental status, disturbance of vision, and equilibrium due to brain stem involvement.\textsuperscript{15} The most widely accepted criteria for a MHI involves an injury that is produced by acceleration and deceleration of the freely moving head, producing a moment of unconsciousness or diminished consciousness after 20 minutes of impact.\textsuperscript{15,16} A concussion is an injury to the brain that may cause instant loss of awareness or alertness
for a few minutes up to a few hours after the traumatic event.

MHI’s are caused by a number of different mechanisms that ultimately result in acceleration, deceleration or rotational forces acting on the brain. Riemann\textsuperscript{16} states that concussion or MHI most often results from a blow to the head that is equivalent to a linear acceleration of 80-90 times the force of gravity for more than a few milliseconds.\textsuperscript{16} Clinicians are often solely dependent on subjective symptoms, most of which are underreported by anxious athletes, rather than the evidence of sound objective data. Subjective signs and symptoms may resolve immediately after injury, although underlying pathology many still remain undetected.\textsuperscript{15}

Guskiewicz\textsuperscript{17} studied 36 NCAA Division 1 collegiate athletes who had sustained a concussion over the season.\textsuperscript{17} The Sensory Organization Test and the Balance Error Scoring System are used to demonstrate postural stability deficits. Results showed that subjects demonstrated postural stability deficits on both tests. Test scores were shown to be lower than baseline measurements. These results show that athletes with cerebral concussion demonstrated acute balance deficits, which are likely the result of not using
information from the vestibular and visual systems effectively.\textsuperscript{17}

Guskiewicz also performed a study that examined alternating ways to measure a MHI.\textsuperscript{15} Eleven college athletes who sustained a MHI were studied. Results demonstrated that postural stability was decreased until the third day post injury. It appears that this deficit is related to a sensory interaction problem, whereby the injured athlete fails to use their visual system effectively. Both of these studies shows that if there is damage to one or more systems that balance can be altered.\textsuperscript{15}

\textbf{Muscle Fatigue in Maintaining Balance}

Muscle fatigue is a normal result of vigorous exercise, but barriers at many of the different stages of muscle contraction may cause abnormal fatigue. Muscle fatigue is the decline in ability of a muscle to create force. An important factor in muscle fatigue is the reduction in the release of calcium ions from the sarcoplasmic reticulum, along with falling ATP levels.\textsuperscript{7} There are two different types of fatigue. Peripheral fatigue is the more local fatigue that affects a muscle of a group of muscles.\textsuperscript{20} Factors that cause peripheral fatigue include metabolic inhibition, and excitation-contraction
coupling failure\textsuperscript{20} of the muscles that are being activated. Central fatigue is the overall perception of exertion coming from respiratory cardiovascular metabolic reaction.\textsuperscript{20}

**Ankle Stability in Maintaining Balance**

Ankle instability can play an important role in maintaining balance. Lentell defines functional ankle instability as an ankle which gives way under normal use.\textsuperscript{21} There are three main reasons presented in literature that explains ankle instability. The first is anatomic instability, the loss of ligament support that is well accepted as the cause of instability.

The second factor that is associated with instability is muscle weakness. Literature associates peroneals\textsuperscript{21} dorsiflexors, and plantar flexors\textsuperscript{20} as the three most common muscles to be weak during an ankle injury.\textsuperscript{21} The third factor is deficits in proprioception that is caused by scarring of the torn ligaments and joint capsules after a serious injury.\textsuperscript{21}

Lentell has suggested that athletes that sustained an ankle injury showed notable difference when they altered the weight bearing leg.\textsuperscript{21} The ankle that demonstrated instability showed a decrease in muscle balance during the Romberg test.\textsuperscript{21}
Balance Testing

Prior to the mid 1980’s, very few methods were used to assess balance. Over the last past decade many new balance testing methods and instruments have been used. The two most commonly used tests that require no special instruments are the modified Romberg test and the Balance Error Scoring System (BESS). The assessment of determining cerebellar function has commonly been done by using the single leg Romberg stance test. However, the single leg Romberg stance test has been criticized for its lack of sensitivity and objectively.

The Romberg Test

Clinicians commonly used the Romberg test as the main field test to examine postural stability. The Romberg test is not very sensitive and rather qualitative because a considerable amount of stress of the postural stability is required to make the patient sway sufficiently to enable an observer to characterized the sway. No research was found that stated a correlation coefficient reliability value for the Romberg test.
A study performed by Riemann\textsuperscript{25} investigated several variations of the Romberg Test that could be used in MHI assessment without needing complex or expensive balance equipment.\textsuperscript{25} Three different stances (double, single, tandem) on two different surfaces (firm and foam) were investigated. Statistical analysis revealed that the original Romberg test might not be sensitive enough to detect deficits in postural stability following MHI. Significant differences were revealed at day one on the single leg stance and the tandem stance. Riemann suggested that these two tests should be considered when performing a sideline or clinical MHI assessment.\textsuperscript{25}

Over the years variations to the Romberg test have been developed and the most commonly used variation is the single leg Romberg stance test.\textsuperscript{1} A study performed on forty-five healthy elderly women assessed the sharpened Romberg Test (SR) and the one-legged stance test (OLST) to two other quick quantitative tests. Results showed that even though the SR and OLST are quick, simple, and inexpensive, they are poorly representative of motor tasks in everyday life.\textsuperscript{26,27} Subjects had a difficult time maintaining balance. They suggest that results may vary if a younger population was used as subjects.
Recent evidence suggests that the best on-the-field balance test uses a tandem stance (heel to toe) performed on a stable and foam surface.\(^1,27\) Normally, athletes can maintain balance by standing motionless during the single leg stance. A positive sign is when the athlete begins to sway, cannot keep their eyes closed, or obviously lose their balance.\(^1,27\) The patient should be able to stand motionless for 30 seconds without touching the non-weight bearing foot to the ground.\(^2\)

The Balance Error Scoring System

BESS serves as a reliable clinical evaluation measure.\(^27\) BESS is a newer clinical test that is recommended over the standard Romberg test.\(^1,20,23\) Hoffman performed a study between Certified Athletic Trainers (ATC) and Athletic Training Students (SAT) to determine the reliability of the BESS system.\(^28\) High intraclass correlation coefficients for both intertester (.78 to .96) and intratester (.87 to .98) were noted.\(^28\) Guskiewicz studied showed that test-retest reliability was found moderate \(r=.673\).\(^15\) These findings suggest that the same clinician should administer the BESS test.

BESS uses three different stances (double, single, tandem) that are completed twice, once while on a firm
surface and once while on a 10-cm thick piece of medium-density foam.\textsuperscript{21,p162} Subjects are instructed to assume the required stance by placing their hands on the iliac crest, and close their eyes for 30 seconds.\textsuperscript{1,14,21}

A study completed by Guskiwicz\textsuperscript{29} showed that subjects that had sustained a MHI had decreased postural stability one day after injury. Based on his findings, the BESS is a practical, valid, and cost effective method of objectively assessing postural stability in athletes suffering from a concussion.\textsuperscript{29}

A study was performed to determined the percent variance associated with each measure of the BESS.\textsuperscript{32} The results showed a intraclass correlation coefficient (R=.604) for all six trials. Double leg stance was removed from the study because the variance was very small, and single leg stance was the highest. Once double leg stance was removed the variance showed a correlation coefficient (R=.706).\textsuperscript{32}

A study performed to determine how long it took to recover after performing the BESS test.\textsuperscript{33} Results showed that exertion harmfully affected balance. These findings suggested that after exertion exercises fatigue could result in false-positive findings while performing the BESS
test immediately after a concussion or a balance deformity.\textsuperscript{33}

A typical sideline evaluation consists of assessing orientation to time, place, person, situation, and simple memory and concentration.\textsuperscript{34} Susco\textsuperscript{33} suggested waiting after the evaluation process to perform the BESS. Waiting 20 minutes to see if any symptoms diminish will help give a better BESS test results. This suggestion will work because the athlete is calm, fatigue is diminished, and disturbances in the visual or somatosensory inputs will be returned to normal giving the certified athletic trainer an accurate finding.

Summary

The ability of the body to maintain its COG over the base of support requires information obtained from proprioception, somatosensory, visual, and vestibular systems. Proprioception is the sense that indicates whether the body is moving with adequate effort, and/or where the various body parts are located in relation to each other. Proprioception relies on sensory and motor control feedback obtained from mechanical receptors found
in the skin, muscle, ligaments, and joints to help the body sense changes along the extremities.

Somatosensory, visual, and vestibular inputs work together to allow the body to sense change in the COG and allows the body to make any required adjustments. Organs of the somatosensory system include pacinian corpuscles, free never endings, Meissner’s corpuscles, and Ruffini endings, which detect the sensations of touch, pressure, vibration, and joint position. GTO’s and muscle spindles, along with the tactile organs, send information to the spinal cord about muscle tension, length, and the rate of changes in length. Once information is received from the spinal cord it travels to the brain stem. Information from the sensory, motor, and central integration helps the body maintain joint stability. Taking away vision helps the body to relearn proprioception. This action makes the adjustment process quicker and accurate. With vision away, the body has to rely on its other senses to maintain balance. Balance is the ability to maintain the body’s COG over its base of support.

Single leg stance occurs frequently within many activities of daily living and sport participation. Stability increases due to the narrow base of support. During the single leg stance, muscles of the ankle
constantly fire to maintain balance. If the body begins to sway, the knee and hip joints come in to help maintain balance and keep the body from falling over.

Internal and external factors can have a negative impact on balance. Conditions such as MHI, ankle instability, and fatigue can alter one’s balance. These factors have been shown to decrease muscle balance during the single leg Romberg stance test and the BESS test. The single leg Romberg stance test has been commonly been used to determine cerebellar function. However, its been criticized for its lack of sensitively to activities of daily living. Considerable amount of stress is placed on postural stability muscles to allow the body to sway. Currently there are no reliability values for the SLR. The BESS test is a newer clinical test that is recommended over the SLR test, because it is a good representation of motor tasks in every day life.
APPENDIX B

The Problem
The Balance Error Scoring System (BESS) is recommended over the modified Romberg test when assisting athletes that have sustained a mild head injury (MHI) or have experienced a balance disability. However, the modified Romberg is used more often then the BESS for a quick quantitative balance assessment. The purpose of this study is to determine the reliability of the single leg Romberg stance test and by comparing it to the BESS test to determine if it is valid for a quick on the field assessment of balance in the college age population.

**Definition of Terms**

The following terms will be defined operational to this study:

1. Balance – a state of bodily equilibrium.\(^{13}\)
2. Balance Error Scoring System – a reliable clinical test to measure postural stability.\(^{14}\)
3. Center of gravity – the point within something at which balance can be considered to act.\(^{14}\)
4. Fatigue – weariness from bodily or mental exertion.\(^{7}\)
5. Free nerve ending – peripheral endings of sensory nerve fibers in which the terminal filaments end freely in the tissue.\(^{8}\)
6. **Golgi tendons** – organs that are located in tendons that respond to sudden increase muscular tension and cause a protective relaxation response.\(^7,\text{8}\)

7. **Homeostasis** – the ability or tendency of an organism or cell to maintain internal equilibrium by adjusting its physiological process.\(^14\)

8. **Instability** – a state of disequilibrium; lack of physical stability; unsteadiness.\(^14\)

9. **Mechanoreceptors** – a specialized sensory end organ that responds to mechanical stimuli such as tension, pressure, or displacement.\(^7\)

10. **Meissner Corpuscles** – located in the skin and are sensitive to touch.\(^8\)

11. **Motor control** – regulation or maintenance of a function or action or reflex.\(^7\)

12. **Motor neuron** – a nerve cell that conducts impulses to a muscle, gland, or other effector.\(^8\)

13. **Muscle spindles** – found in the belly of the muscle that respond to the change and the rate of change in a muscle length.\(^8\)

14. **Neuromuscular control** – unconscious activation of dynamic restraints occurring in preparation for and in the response of joint motion and loading for the purpose of maintaining the alignment.\(^6\)
15. Pacinian Corpuscles – small oval bodies terminating some of the minute branches of the sensory nerves in the integument and other parts of the body. 

16. Proprioception – the ability to sense that position and location and orientation and movement of the body and its parts.

17. Proprioceptive feedback – continuing process that gains information by the afferent pathway that carry proprioception information.

18. Receptors – a specialized cell or group of nerve endings that responds to sensory stimuli.

19. Romberg test – a qualitative test for assessing balance; the presence of Romberg’s sign is by placing the feet together and closing the eyes.

20. Ruffini endings – nerve endings that are found in the deep dermis of the skin respond to tension and stretch of the skin.

21. Somatosensory – of or pertaining to sensations that involve parts of the body not associated with the primary sense organs.

22. Static stability – the ability to maintain the center of gravity over the base of support.
Basic Assumptions

The following assumptions will be made for this study:

1. The Single Leg stance and the Balance Error Scoring System are reliable quantitative
2. Somatosensory input was reduced by the use of medium-density foam.
3. Subject put forth their best efforts to maintain balance.
4. Subjects are honest about visual, vestibular, or balance disorders, lower extremity injury, and/or concussion within the last six months will be excluded from this study as these conditions may interfere with accurate balance assessment.

Limitation

The following limitation will be made for this study.
1. Limitations of findings may be limited to the college age students.
Significance of the Study

Certified athletic trainers and team physicians are often faced with decisions about the severity of an injury and the timing of an athlete’s return to play after a mild head injury. The complexity of the brain and the few objective signs often manifested at the time of injury makes the assessment challenging. This topic in the sports medicine field is under considerable debate due to the lack of objective information that is obtained from athletes on his or her status. Athletes may lie on how they are truly feeling to be able to return to the game or practice.

The body is not a rigid form and sways while standing upright. When standing on one leg the ankle performs small oscillations about the vertical axis to help keep the body upright. Several systems have been used to assess balance. The two most often used tests for a quick assessment of balance are Single Leg Romberg and the Balance Error Scoring System.
APPENDIX C

Additional Methods
APPENDIX C1

Informed of Consent Form
Informed of Consent Form

1. Samantha J. Machnik who is a graduate student at California University of Pennsylvania has requested my participation in a research study at this institution. The title of the study is “Reliability of the Single leg Romberg stance test Compared to the Balance Error Scoring System.”

2. I have been informed that the purpose of the research is to determine which balance test is more reliable. There will be approximately 21 subjects participating in this study, and I have fulfilled the requirements to participate in this study.

3. My participation will involve performing the Single Leg Romberg test, and the Balance Error Scoring System for a total of two tests. Each trial for the BESS test will last 20 seconds, and the single leg Romberg stance test for 60 seconds with a one-minute rest in between testing. My expected time to complete this study will be approximately 15-20 minutes.

4. I understand that there are foreseeable risks or discomforts by participating in this study such as lower extremity injury. However, I understand that by following the procedures of administering the tests the researcher will minimize these risks.

5. There are no feasible alternative procedures available for this study.

6. I understand that the possible benefits of my participation in the research are to help determine the reliability of the single leg Romberg stance test and determine what test will be more reliable for a clinical field assessment of balance. This study can help certified athletic trainers to better determine balance deformities and rehabilitation of lower extremity injuries.

7. I understand that the results of the research study may be published but my name or identity will not be revealed. In order to maintain confidentially of my records, Samantha J. Machnik will maintain all
documents in a secure location in which only the student researcher and research advisor can access. Each subject will be given a specific number to represent his or her name.

8. I have been informed that I will not be compensated for my participation.

9. I have been informed that any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by Samantha J. Machnik  
   mac1673@cup.edu  
   PO Box 116 Fairbank, PA 15435  
   724-557-7064

   Thomas F. West, PhD, ATC  
   west_t@cup.edu  
   724-809-1321

10. I understand that written responses may be used in quotations for publication but my identity will remain anonymous.

11. I have read the above information. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me upon request.

Subject's signature____________________Date:___________

Other signature:____________________Date_____________
12. I certify that I have explained to the above individual the nature and purpose, the potential benefits, and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature.

13. I have provided the subject/participant a copy of this signed consent document if requested.

Investigator’s signature__________________________________Date________

Approved by the California University of Pennsylvania IRB
APPENDIX C2

Demographic Sheet
Demographic Sheet

Subject ID Number:________________________ Date:_________________

Age:________

Height:_______

Weight:_______

Gender:_______

Packet Number:________

Subjects will report their own weight and height honestly.
APPENDIX C3

Balance Error Scoring System
How to perform the BESS test:

The BESS is performed on three different stances (double, single, tandem), and on two different surfaces (flat, and medium density foam pad). Each stance is completed once on each surface. Progression goes from easiest (Picture A) to hardest (Picture F). Patients are asked to assume the required stance by placing their hands on the iliac crest and upon eye closure the 20 seconds test begins. During the single leg stance tests the subjects are asked to maintain the non-weight bearing leg at 40-50 degrees of knee flexion and 20-30 degrees of hip flexion. Additionally, the patient is asked to stand quietly and still as possible keeping their hands on the iliac crest and eyes closed. The single leg stances are performed on the non-dominant leg. This same foot is placed toward the rear on the tandem stance. Subjects are told upon losing their balance they are to make any necessary adjustments and return to the testing position as quickly as possible. Adding one error point for each error committed scores performance, and these trials are assigned a standard maximum error score of 10. The higher the score the worse the subject balance is.¹
APPENDIX C4

Balance Error Scoring System Point Scale
### BESS SCORING TABLE

<table>
<thead>
<tr>
<th>Event</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands lift off of iliac crest</td>
<td>1 point</td>
</tr>
<tr>
<td>Opening of the eyes</td>
<td>1 point</td>
</tr>
<tr>
<td>Step, Stumble, or fall</td>
<td>1 point</td>
</tr>
<tr>
<td>Moving hips beyond 30° of flexion</td>
<td>1 point</td>
</tr>
<tr>
<td>Lifting forefoot or heel</td>
<td>1 point</td>
</tr>
<tr>
<td>Remaining out of testing procedure &lt; 5</td>
<td>1 point</td>
</tr>
</tbody>
</table>

Adding one error point for each error committed scores performance, and these trials are assigned a standard maximum error score of 10. The higher the score the worse the subject balance is. ³,¹²
APPENDIX C5

Institutional Review Board (IRB)
California University of Pennsylvania

PROTOCOL for Research Involving Human Subjects

Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects

(Reference IRB Policies and Procedures for clarification)

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Project Title: Reliability of the Single Leg Romberg in comparison to the Balance Error Scoring System

Researcher/Project Director: Samantha J. Machnik

Phone #: 724-557-7064   E-mail Address: mac1673@cup.edu

Faculty Sponsor (if required): Dr. Tom West

Department: Health and Science

Project Dates: Fall 2006 to Spring 2007

Sponsoring Agent (if applicable)

Project to be Conducted at: California University of Pennsylvania Dance Studio

Project Purpose:  ☒ Thesis  ☐ Research  ☐ Class Project  ☐ Other

Keep a copy of this form for your records.
Required IRB Training

The training requirement can be satisfied by completing the online training session at http://cme.nci.nih.gov/. A copy of your certification of training must be attached to this IRB Protocol. If you have completed the training at an earlier date and have already provided documentation to the California University of Pennsylvania Grants Office, please provide the following:

Previous Project Title

Date of Previous IRB Protocol

Training requirement has been completed and the certificate will be sent through the mail.
Please attach a typed, detailed summary of your project AND complete items 2 through 6.

1. Provide an overview of your project-proposal describing what you plan to do and how you will go about doing it. Include any hypotheses or research questions that might be involved and explain how the information you gather will be analyzed. For a complete list of what should be included in your summary, please refer to Appendix B of the IRB Policies and Procedures Manual.

2. Section 46.11 of the Federal Regulations state that research proposals involving human subjects must satisfy certain requirements before the IRB can grant approval. You should describe in detail how the following requirements will be satisfied. Be sure to address each area separately.

   a. How will you insure that any risks to subjects are minimized? If there are potential risks, describe what will be done to minimize these risks. If there are risks, describe why the risks to participants are reasonable in relation to the anticipated benefits.
b. How will you insure that the selection of subjects is equitable? Take into account your purpose(s). Be sure you address research problems involving vulnerable populations such as children, prisoners, pregnant women, mentally disabled persons, and economically or educationally disadvantaged persons. If this is an in-class project describe how you will minimize the possibility that students will feel coerced.

c. How will you obtain informed consent from each participant or the subject’s legally authorized representative and ensure that all consent forms are appropriately documented? Be sure to attach a copy of your consent form to the project summary.

d. Show that the research plan makes provisions to monitor the data collected to insure the safety of all subjects. This includes the privacy of subjects’ responses and provisions for maintaining the security and confidentiality of the data.

3. Check the appropriate box(es) that describe the subjects you plan to use.
4. Is remuneration involved in your project?  □ Yes or  ☒ No. If yes, Explain here.

5. Is this project part of a grant?  □ Yes or  ☒ No  If yes, provide the following information:

   Title of the Grant Proposal  ____________________________

   Name of the Funding Agency  ____________________________

   Dates of the Project Period  ____________________________

6. Does your project involve the debriefing of those who participated?  □ Yes or  ☒ No
If Yes, explain the debriefing process here.

7. If your project involves a questionnaire interview, ensure that it meets the requirements of Appendix __ in the Policies and Procedures Manual.
Project Director's Certification
Program Involving HUMAN SUBJECTS

The proposed investigation involves the use of human subjects and I am submitting the complete application form and project description to the Institutional Review Board for Research Involving Human Subjects.

I understand that Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects. If the Board grants approval of this application, I agree to:

1. Abide by any conditions or changes in the project required by the Board.
2. Report to the Board any change in the research plan that affects the method of using human subjects before such change is instituted.
3. Report to the Board any problems that arise in connection with the use of human subjects.
4. Seek advice of the Board whenever I believe such advice is necessary or would be helpful.
5. Secure the informed, written consent of all human subjects participating in the project.
6. Cooperate with the Board in its effort to provide a continuing review after investigations have been initiated.

I have reviewed the Federal and State regulations concerning the use of human subjects in research and training programs and the guidelines. I agree to abide by the regulations and guidelines aforementioned and will adhere to policies and procedures described in my application. I understand that changes to the research must be approved by the IRB before they are implemented.

Professional Research

<table>
<thead>
<tr>
<th>Project Director’s Signature</th>
<th>Department Chairperson’s Signature</th>
</tr>
</thead>
</table>
Student or Class Research

Samantha J. MacRae
Student Researcher’s Signature

Supervising Faculty
Member’s Signature if required

W. B. Batch
Department Chairperson’s Signature

ACTION OF REVIEW BOARD (IRB use only)

The Institutional Review Board for Research Involving Human Subjects has reviewed this application to ascertain whether or not the proposed project:

1. provides adequate safeguards of the rights and welfare of human subjects involved in the investigations;
2. uses appropriate methods to obtain informed, written consent;
3. indicates that the potential benefits of the investigation substantially outweigh the risk involved.
4. provides adequate debriefing of human participants.
5. provides adequate follow-up services to participants who may have incurred physical, mental, or emotional harm.

☑ Approved  ☐ Disapproved  12/06/06
Chairperson, Institutional Review Board Date
1. The purpose of this study is to determine which balance test is more reliable in the college aged group. Before testing procedures take place, subjects will sign an informed consent form. This study will be a correlation design.

Healthy college students from California University of Pennsylvania will volunteer in this study. Students participating in the athletic training undergrad and graduate programs will be asked to participate. Subjects will be asked if they had any previous Mild head injury (MHI) within the last past six months, taking any medication that may hinder their balance, or had a surgery within a year as these conditions may interfere with accurate balance assessment.

Subjects will be asked to perform these balance tests in one testing section. Subjects will do one practice trial for each test. SRL measures how long they can stand in the testing position. BESS test will measure how many times the subject moves out of testing position.

**SRL**

Subjects will be asked to stand still on their dominant foot. To determine their dominant foot, the researcher will ask the subjects to kick a ball. The foot that they chose to use will be their dominant foot. The subjects will place their hands on their iliac crest and close their eyes. The time that it takes them to touch the non-weight bearing leg to the ground will be recorded. Once the non-weight bearing leg touches the ground the test is completed.

**BESS - Double Leg Stance**

The subjects will perform this test on both surfaces (flat floor, medium-density foam) barefoot for 20s. The subject will be asked to close their eyes, place their hands on their iliac crest, place feet together, and stand still. Each time an error is performed a point will be given. Scores will be added up after the 20s is completed.
BESS - Single Leg Stance
The subject will perform this test on both surfaces barefoot on their non-dominant leg. To determine their non-dominant foot, the researcher will ask the subjects to kick a ball. The foot that they chose not to use will be their non-dominant foot. Their non-weight bearing leg will be placed at 20-30° of hip flexion and 40-50° of knee flexion. Subjects will be asked to place their hands on their iliac crest, close their eyes, and place their hip and knee in the recommended angles. Scores will be added up after the 20s is completed.

BESS - Tandem stance
Subjects will be asked to place their non-dominant leg behind their dominant leg and will be asked to stand in a heel-to-toe manner. The subject will then be asked to close their eyes, and place their hands on their iliac crest. The subject will be tested on both surfaces, barefoot for 20s.

I believe that there will be a positive relationship between the Single Leg Romberg time and the BESS points. As the time on the Single Leg Romberg decreases, points on the BESS will increase. A Pearson correlation analysis will be performed to see if there is a significant relationship found between the scores of the Single Leg Romberg and the BESS scores. Correlation statistics will be evaluated using the SPSS for windows 13.0 with an alpha level at < 0.05.

2a. By following procedures of administering the tests, risk to subjects will be reduced. Subjects will be monitored at all times. There will be a person standing behind them to reduce the risk of falling. This study does not put the subjects in a situation that exceeds the activities of daily living. Subjects are free to discontinue from participation any time during the testing procedures.

2b. Healthy college students from California University of Pennsylvania will participate in this study. Students
who are participating in the undergraduate and graduate programs will be asked to volunteer. Any subject who has suffered from visual, vestibular, or balance disorders, lower extremity injury, and/or concussion within the last six months will be excluded from this study as these conditions may interfere with accurate balance assessment. If yes they will be eliminated from the study.

2c. On the day that the test will be administered the subjects will be asked to sign an informed consent form. They will be signing the consent form prior to any testing, in front of the tester to make sure that it is filled out correctly.

2d. Data collection will be done by the researcher. All files will be kept confident. Each subject will be given a number to replace their names so their identity will be kept safe. Only the student researcher and the researcher advisor will have access to these records.
APPENDIX C6

Score Sheet for the Balance Error Scoring System and the single leg Romberg stance test
Score Sheet

Subject ID Number:_______________  Date:_______________

BESS-Firm surface

<table>
<thead>
<tr>
<th>Errors</th>
<th>Practice Trial (double leg)</th>
<th>Double Leg</th>
<th>Practice Trial (single leg)</th>
<th>Single Leg</th>
<th>Practice Trial (Tandem)</th>
<th>Tandem Stance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands off iliac crest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open eyes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stumble, fall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heel/foot lifts off</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out of testing position &lt;5s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Move hips/knees out of ranges</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**BESS-foam surface**

<table>
<thead>
<tr>
<th>Errors</th>
<th>Practice Trial (double leg)</th>
<th>Double Leg</th>
<th>Practice Trial (single leg)</th>
<th>Single Leg</th>
<th>Practice Trial (Tandem)</th>
<th>Tandem Stance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands off iliac crest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open eyes</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Stumble</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heel/foot lifts off</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out of testing position &lt;5s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Move hips/knees out of ranges</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Single Leg Romberg**

<table>
<thead>
<tr>
<th>Practice trial</th>
<th>Testing trial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix C7

Testing Procedures
Before testing will be performed, the volunteers will do the following:

- Read and sign the inform of consent form
- Complete the demographic sheet (subject ID number is the number sign in as)
- Select a number from a basket. The number will determine what order the testing will be in. A number 1 will determine that the single leg romberg stance test will be performed 1st followed by the BESS. A number 2 will determine that the subject will perform the BESS test first then the Single leg romberg.

Total time ~5 minutes

Both tests will be initiated from the command to begin (ready, go) and end after Stop. Subjects will be giving one practice trial for each test.

**Single leg Romberg**

Please remove your shoes and socks. To help you familiarize yourself with the test, you will be performing 1 practice trial. If you would be asked to kick a soccer ball, which foot would you use? For testing purposes, you will be standing on your other leg.

During this test you will be asked to place your hands on your hips and keep your eyes closed. When I say go you will close your eyes and lift up you dominate (kicking) leg.

The test will stop once the non-weight bearing leg touches the ground, or when you step out of the testing position. The test will begin when I say “go” and will end when I say “stop”. If you start to sway and stumble try to return to the testing stance as soon as possible. If you remain in testing position for 1 min testing will stop. Once I say stop please have a seat in the chair and rest for 1 min. After the 1 minute rest, you will perform this test again, and your time will be recorded.

Total time ~ 3 mins

**BESS double leg stance –floor**

To help you familiarize yourself with the test, you will be performing 1 practice trial. Place your feet shoulder width apart, hands on your iliac crest, and stand still. As you perform this test, I will be marking down any errors that I see. The test is 20 seconds long. Test will begin on the command of ready, go, and stop at the command of stop. If you feel that you are stumbling or falling, return to the testing position as soon as possible. Once I say go you will close your eyes, keep your feet shoulder width apart, and hands on your hips. Once I say stop you will have a seat for a minute. After the minute rest you will come and perform the test again and your errors will be recorded.

~ time 2 mins

**BESS single leg stance –floor**

To help you familiarize yourself with the test, you will be performing 1 practice trial. If you were asked to kick a soccer ball, which foot would you use? For testing purposes, you will be standing on your other leg. As you perform this test, I will be marking down
any errors that I see. During this test you will be asked to maintain your hands on your hips, and keep your eyes closed. When I say go you will close your eyes and lift up you dominate (kicking) leg. The test will begin when I say “go” and will end when I say “stop”. If you start to sway and stumble try to return to the testing stance as soon as possible. If your non-weight bearing leg touches the ground just lift it back up. The test is 20 seconds long. Once I say stop please have a seat in the chair and rest for 1 min. After the 1-minute rest, you will perform this test again, and your time will be recorded.

~ time 2 minutes

**BESS tandem stance – floor**

To help you familiarize yourself with the test, you will be performing 1 practice trial. As you perform this test, I will be marking down any errors that I see. For this test you will place your non-dominant leg behind your kicking leg and will stand in a heel-to-toe manner. Place your hands on your hips and on the command of go close your eyes. This test will last 20 seconds. The test will begin when I say “go” and will end when I say “stop”. If you start to sway and stumble try to return to the testing stance as soon as possible. Once I say stop please have a seat in the chair and rest for 1 min. After the 1-minute rest, you will perform this test again, and your time will be recorded.

~ time 2 minutes

**BESS double leg stance – Pad**

To help you familiarize yourself with the test, you will be performing 1 practice trial. Stand on the foam pad, and place your feet shoulder width apart, hands on your iliac crest, and stand still. As you perform this test, I will be marking down any errors that I see. The test is 20 seconds long. Test will begin on the command of ready, go, and stop at the command of stop. If you feel that you are stumbling or falling, return to the testing position as soon as possible. Once I say go you will close your eyes, keep your feet shoulder width apart, and hands on your hips. Once I say stop you will have a seat for a minute. After the minute rest you will come and perform the test again and your errors will be recorded.

~ time 2 minutes

**BESS single leg stance – foam pad**

To help you familiarize yourself with the test, you will be performing 1 practice trial. If you would be asked to kick a soccer ball, which foot would you used? For testing purposes, you will be standing on your other leg. As you perform this test, I will be marking down any errors that I see. Please stand on the foam pad. During this test you will be asked to maintain your hands on your hips, and keep your eyes closed. When I say go you will close your eyes and lift up you dominate (kicking) leg. The test will begin when I say “go” and will end when I say “stop”. If you start to sway and stumble try to return to the testing stance as soon as possible. If your non-weight bearing leg
touches the ground just lift it back up. The test is 20 seconds long. Once I say stop please have a seat in the chair and rest for 1 min. After the 1-minute rest, you will perform this test again, and your time will be recorded.

~ time 2 minutes

**BESS tandem stance – foam pad**

To help you familiarize yourself with the test, you will be performing 1 practice trial. As you perform this test, I will be marking down any errors that I see. Please stand on the foam pad. For this test you will place your non-dominant leg behind your kicking leg and will stand in a heel-to-toe manner. Place your hands on your hips and on the command of go close your eyes. This test will last 20 seconds. The test will begin when I say “go” and will end when I say “stop”. If you start to sway and stumble try to return to the testing stance as soon as possible. Once I say stop please have a seat in the chair and rest for 1 min. After the 1-minute rest, you will perform this test again, and your time will be recorded.

~ time 2 minutes

Total time = ~ 20 minutes
REFERENCES


ABSTRACT

Title: RELIABILITY OF THE SINGLE LEG ROMBERG STANCE TEST COMPARED TO THE BALANCE ERROR SCORING SYSTEM

Researcher: Samantha J. Machnik

Advisor: Dr. Thomas West

Date: May 2007

Research Type: Master’s Thesis

Purpose: This study determined the reliability of the single leg Romberg stance test and compared it to the BESS to determine what test is more reliable in the college population.

Problem: Athletic trainers commonly used the Romberg test after a suspected MHI. However, currently there is no reliability value found in literature on the college age population. The BESS test is a clinical test that is recommended over the Romberg test.

Method: A one shot experimental design was used. Twenty-one athletic training students from California University of Pennsylvania volunteered. The instruments used were a demographic sheet, Romberg, and BESS tests.

Findings: The Romberg test was found to be a reliable balance test. A strong negative correlation was found between the two tests.

Conclusion: The Romberg can be used as an on-the-field assessment of balance because it is quick. BESS can be used as a clinical assessment because of equipment used.

Key Words: Reliability, balance assessment, BESS, Romberg