RELIABILITY OF THE BALANCE ERROR SCORING SYSTEM PROTOCOL ON THE BIODEX BALANCE SYSTEM

A Thesis

Presented to

The Graduate Faculty of The University of Akron

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Kristin Marie Knapp

May, 2013
RELIABILITY OF THE BALANCE ERROR SCORING SYSTEM PROTOCOL ON
THE BIODEX BALANCE SYSTEM

Kristin Marie Knapp

Thesis

Approved:  Accepted:

Thesis Advisor/Chair  Associate Dean of the College
Dr. Ronald Otterstetter  Dr. Susan Olson

Committee Member  Dean of the Graduate School
Mrs. Carrie Fister  Dr. George R. Newkome

Committee Member  Date
Mrs. Rachele Kappler

Department Chair
Dr. Victor Pinheiro
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>v</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I.   INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II.  REVIEW OF LITERATURE</td>
<td>7</td>
</tr>
<tr>
<td>Introduction</td>
<td>7</td>
</tr>
<tr>
<td>Concussion</td>
<td>7</td>
</tr>
<tr>
<td>Concussion Evaluation Techniques</td>
<td>9</td>
</tr>
<tr>
<td>Balance and Concussion</td>
<td>13</td>
</tr>
<tr>
<td>Conclusion</td>
<td>20</td>
</tr>
<tr>
<td>III. METHODS</td>
<td>21</td>
</tr>
<tr>
<td>Participants</td>
<td>21</td>
</tr>
<tr>
<td>Instruments</td>
<td>22</td>
</tr>
<tr>
<td>Research Design</td>
<td>22</td>
</tr>
<tr>
<td>Statistical Design</td>
<td>24</td>
</tr>
<tr>
<td>IV.  RESULTS</td>
<td>26</td>
</tr>
<tr>
<td>V.   SUMMARY</td>
<td>29</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>36</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>40</td>
</tr>
</tbody>
</table>

iii
APPENDIX A. INFORMED CONSENT FORM ................................................................. 41
APPENDIX B. BESS SCRIPT .................................................................................... 45
APPENDIX C. HUMAN SUBJECTS APPROVAL FORM ............................................ 48
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Participant Physical Characteristics</td>
<td>26</td>
</tr>
<tr>
<td>2. Pearson Product Moment Correlations between OSI trials</td>
<td>27</td>
</tr>
<tr>
<td>3. Pearson Product Moment Correlations between BESS trials</td>
<td>28</td>
</tr>
<tr>
<td>4. Pearson Product Moment Correlations between BESS and OSI trials</td>
<td>28</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

Sport concussions have become a large area of study for physicians, athletic trainers, and other medical professionals in the past couple decades due to the increased popularity and participation in youth, high school, collegiate, professional, and recreational sports. The Center for Disease Control and Prevention (CDC) report that approximately 38 million children and 170 million adults participate in organized sports or physical activity each year (CDC, 2007). Americans are fond of watching and taking part in many athletic events, which means that those in the health care industry need to make it a priority to minimize the risk of injury. Now that research is being done to help prevent, evaluate, and properly assess concussions it is imperative that clinical practice aligns itself with the research.

A concussion is a traumatic brain injury that alters the way the brain functions. The effects are usually temporary, but can include long-term problems with headache, concentration, memory, judgment, balance, and coordination (“Concussion,” 2011). Concussions are thought to occur from a direct hit to the head, however, they can also occur when the head and upper body shake violently (“Concussion,” 2011). The signs and symptoms of concussion can be subtle, but they can last for days, weeks, or even longer. Research suggests that once a person has experienced one concussion they are more susceptible to another, especially if the brain is not completely healed from the
previous concussion (“Concussion,” 2011). This could lead to a much more serious and even life-threatening condition known as Second-Impact Syndrome.

Second-Impact Syndrome (SIS) is a condition where the brain swells rapidly after a person suffers a second concussion before symptoms from an earlier one have subsided. The National Center for Catastrophic Sport Injury Research reported 35 probable incidences of SIS from 1980-1993 (Cantu, 1998). SIS is often fatal and nearly everyone that is not killed is severely disabled. Most cases of SIS have occurred to younger athletes and they are thought to be most at risk. This is one of the reasons that medical professionals need to take extra precautions in regards to head injuries. Athletes should not return to play until all of their symptoms have resolved and have performed a detailed five-phase return to play progression.

It is extremely important that athletic trainers are able to accurately evaluate a concussion and refer the athlete to a sports medicine physician for diagnoses. In recent years, there has been an increase in research performed on concussed athletes, so that athletic trainers may be able to have more objective means of assessing concussions. The current evaluation techniques pay special attention to the athlete’s signs and symptoms, neurocognition, and postural stability.

This study focused in particular on determining what balance assessment tests are reliable for proper diagnosis of a concussion. Literature reveals that the areas of the brain most affected as a result of a concussion are responsible for equilibrium and postural stability (Guskeiwicz, Riemann, Perrin, & Nashner, 1997). Balance is defined as the “process of maintaining the center of gravity (COG) within the body’s base of support
and many factors enter into the task of controlling balance within the designated area” (Guskiewicz, 2001, p. 183). The somatosensory, vestibular, and visual sensory systems all have to be properly working in conjunction to maintain normal balance. When one or more of these systems is not functioning correctly the athlete will display postural stability deficits.

The most commonly used postural stability test in athletics is the Balance Error Scoring System (BESS). The BESS is made-up of six 20-second conditions. These include: double leg, single leg, and tandem stances on a solid surface with eyes closed, and then repeated on a foam pad with eyes closed. The athletes are instructed to stand in these particular positions with their hands on the iliac crest; eyes closed, and chin level. Errors are scored and added together to determine the athlete’s overall balance score. An error is described as any deviation from the stance. For example, moving hands off of the iliac crest, opening the eyes, step, stumble, or fall, abduction or flexion of the hip greater than 30 degrees, lifting the forefoot or heel off the testing surface, or remaining out of the proper testing stance for greater than 5 seconds (McCrory et al., 2009). Subjects that cannot perform the test for at least a minimum of 5 seconds are assigned the highest possible score for that particular condition. The maximum amount of errors for each position is ten. The more errors produced, the worse the balance.

The BESS is an excellent test when assessing an athletes’ balance on the sidelines during a practice or game after a suspected concussion. However, various researchers and medical professionals believe that the BESS is subjective in nature and does not provide much objective findings that may detect the subtle postural stability deficiencies post-concussion. BESS seems to correlate well with other postural stability tests, such as the
Sensory Organization Test performed on the NeuroCom Smart Balance Master System (Guskiewicz, Ross, & Marshall, 2001). Both of these tests showed balance deficiencies 3 days following a concussion with scores improving by day 7 (Guskiewicz, Ross, and Marshall, 2001). However, some studies suggest that a significant learning effect takes place when the subjects are examined in close succession, like the research study previously mentioned. Valovich, Perrin, and Gansneder, (2003) demonstrated that with repeated administration of the BESS the practice group showed significant improvements compared to the control group. Thus, clinicians need to be highly aware that multiple test exposures may elicit better test scores, which may mask concussion related balance deficiencies.

Another downfall of the BESS is the wide range of interrater reliability scores. For example, one study suggests that the interrater reliability ICC of BESS is less than $r = 0.75$. These results imply that when two different examiners are administering the BESS to an athlete the scores reported are not reliable (Finnoff, Peterson, Hollman, & Smith, 2009). Yet, in another study the interrater reliability ICCs were recorded as $r = 0.78$ to 0.93 (Reimann, Guskiewicz, & Shields, 2009). This wide array of data suggests that many factors can contribute to inconsistency of the BESS such as, the experience of the examiners, and the subjectivity of counting errors accurately.

Lastly, the test-retest reliability examined in 2009 implies that the full BESS has low to moderate intra-class and test-retest reliability ($r = 0.60, 0.67$), yet the modified BESS met traditionally accepted measures of reliability (Hunt, Ferrara, Bornstein, & Baumgartner, 2009). However, the modified BESS that was confirmed to be more reliable only used the single-leg and tandem stances on both the firm and foam surfaces.
The Biodex Balance System (BBS) is traditionally designed to improve balance, increase muscle tone, and provide fall risk screening and prevention (Biodex Medical Systems, Inc., 2011). Clinicians are able to use this tool as a training device or testing device to assess neuromuscular control following an injury. It can evaluate bilateral or unilateral postural stability on either a dynamic or static platform. Within the past year and a half, Biodex has added a concussion management program. It utilizes the modified Clinical Test of Sensory Interaction and Balance (m-CTSIB). This test has been used to “systematically remove or conflict sensory input from one or more of the three senses” (Guskiewicz, 2001, p. 183). The m-CTSIB on the BBS includes four 30-second trials all in a bilateral stance with feet and ankle bones together, eyes open and then eyes closed, on a stable surface and then again on a foam surface. The objective of this test is to quantitatively determine a subjects’ score, which will define the ability to maintain a stable vertical posture while on a stationary platform (Biodex Medical Systems, Inc., 2011). It does this by examining the overall sway index (OSI). The OSI is the standard deviation of the stability index. The stability index is the average position from center and it does not determine how much the person swayed only their position on the platform. The higher the sway index the more unstable the patient is during the test. The OSI takes into account the center of gravity (COG) in the anterior-posterior sagittal plane and the medial-lateral frontal plane (Biodex Medical Systems, Inc., 2011).

Therefore, the relationship between the BBS and the current balance assessment techniques seems to be indecisive. More recently, the manufactures of the Biodex Medical system have added a concussion protocol to BBS, and thus far limited research exists. Additionally, to our knowledge only one study has examined the concussion
protocol on the BBS through Biodex. However, this study was only performed to
determine normative values and reliability. A benefit of testing postural stability
following a concussion on the BBS is that it may be able to detect more subtle balance
deficiencies than the clinicians using the BESS. The subjectivity of the BESS is perhaps
the main reason why research data is non-uniform. Therefore, the purpose of this study
was to validate the Biodex Balance System as an objective and reliable tool for
conclusion assessment. A second purpose of this study was to determine the relationship
of the traditional BESS scores and the OSI while performing the BESS on the BBS.
Specifically, the researcher aimed to answer the following questions:

(1) What is the test-retest reliability of the BESS on the BBS?

(2) What is the relationship between the BESS error scores and the OSI scores on the
BBS?
CHAPTER II

REVIEW OF LITERATURE

Introduction

The review of literature has been divided into three main sections. The first provides an overview of concussions: definition, etiology, and the effects of it. The second section addresses the literature related to specific types of post-concussion evaluations and the third section examines in particular balance deficits related to concussions and evaluation of balance following a concussion.

Concussion

A concussion or mild traumatic brain injury (TBI) is an acceleration-deceleration injury that occurs to the head causing an alteration in mental status. The Consensus Statement on Concussion in Sport defines a concussion as a “complex pathophysiological process affecting the brain, produced by traumatic biomechanical forces” (McCrory, Meeuwisse, Johnston, Dvorak, Aubrey, Molloy, & Cantu, 2008). It also states that a direct blow to the head, neck, or face may cause a concussion or rapid onset of neurological impairment that usually resolves spontaneously. The CDC estimates that 1.1 million people each year are treated and released with a nonfatal mild traumatic brain injury (2007). Concussions are relatively common affecting about 128 people per 100,000 in the United States yearly (Bey & Ostick, 2009). Three types of stresses are
reported to cause mild traumatic brain injury, which are compressive, tensile, and shearing (Guskiewicz, Bruce, Cantu, Ferrara, Kelly, McCrea, Putukian & McLeod, 2004). The neural tissue tolerates compressive forces much better than the shear or tensile forces. Research suggests that after an athlete sustains a mild brain injury a cascade of ionic, metabolic, and physiologic events occur, which can negatively affect the brain for days or even weeks (McCrea et al, 2003). A person with a concussion may exhibit: headache, nausea, vomiting, dizziness, balance problems, fatigue, difficulty sleeping, drowsiness, light sensitivity, noise sensitivity, blurred vision, and memory difficulty (McCrea, Guskiewicz, Marshall, Barr, Randolph, Cantu, Onate & Yang, 2003). Loss of consciousness (LOC) may or may not occur with a concussion. The identification of LOC can be difficult, because the athlete may lose consciousness very briefly and will go unnoticed by other players. If LOC is suspected the athlete must be managed conservatively. However, one of the myths about concussions is that one must lose consciousness in order to have sustained a concussion. Yet, LOC is reported only in 8.9% of diagnosed concussions (Oliaro, Anderson & Hooker, 2001).

Despite the advancement in protective equipment and rule changes the incidence rate of concussion occurring in a contact sport are still relatively high. Notebaert & Guskiewicz (2005) report that certified athletic trainers assess on average 8.2 concussions per year. Therefore athletic trainers should have a high sensitivity for concussion diagnosis if the athlete exhibits signs of a mild head injury even without LOC.
Concussion Evaluation Techniques

There has been a growing interest and concern regarding return to play protocols following a TBI partially due to the media coverage surrounding Second-Impact Syndrome (SIS). The National Center for Catastrophic Sport Injury Research reported 35 probable incidences of SIS from 1980-1993 (Cantu, 1998). Another study that examined American high school and college football players confirmed 94 cases of catastrophic brain injury over a 13-year period (Boden, Tachetti, Cantu, Knowles, & Mueller, 2007). Even though SIS is rare the consequences can be devastating. Second-Impact Syndrome is defined as diffuse cerebral swelling and potential death, occurring from a second hit to the head when the athlete is not fully recovered from the first concussion. At the time of the SIS the athlete typically seems stunned and frequently can walk off the field before they collapse. The athlete then becomes “semiconscious with rapidly dilating pupils, fixed eye movements, and experiences respiratory and brainstem failure, usually within 2-5 minutes of the second impact” (Cobb & Battin, 2004, p. 264). Therefore, it is crucial for the athletic trainer and physician to utilize a standard and thorough return to play protocol following concussion.

Regardless of all of the research being performed on concussions, inadequate amounts of evidence-based recommendations are available for clinicians to guide in making proper return to play decisions. Previously, a grading system was the preferred method to assess a concussion and guide the return to play decision. The original Cantu Grading System for Concussion was the most known and readily used method of grading the severity of a concussion. These grading systems tried to label the severity of concussion on whether there was any loss of consciousness or retrograde/antegrade
amnesia (Cantu, 2001). However, at this time clinicians are focusing on the athlete’s recovery by assessing their symptoms, neurocognitive testing, and postural stability testing (Guskiewicz, et al., 2004). These methods appear to be a more objective way to measure the severity of a concussion and provide the optimal strategy for making difficult return to play decisions for concussed athletes.

The most current recommendations for the diagnosis of a concussion come from the 3rd International Conference on Concussion in Sport that was held in Zurich in 2008. The recommendations suggest that a range of domains must be evaluated for the diagnosis of a concussion. These domains include: symptoms, physical signs, behavioral changes, cognitive impairment, and sleep disturbances (McCrory, Meeuwisse, Johnston, Dvorak, Aubrey, Molloy, & Cantu, 2008).

The Sport Concussion Assessment Tool (SCAT 2) clearly outlines and assesses each of these domains. The original SCAT was published in 2005, however in 2008 the SCAT 2 replaced the original. The SCAT 2 should be given at the beginning of the season for baseline testing and then utilized again if the athlete has a suspected mTBI. This tool incorporates the Standardized Assessment of Concussion (SAC), the Maddocks questions, the Glasgow Coma Scale, the BESS test for postural stability, and the signs and symptoms checklist. The SAC is the cognitive assessment portion of the SCAT 2 in which it contributes to determine orientation, immediate memory, concentration, and delayed memory recall. The Maddocks Questions are a set of orientation questions used to qualitatively assess a person’s mental status and are a useful starting point of the initial assessment of a head injury. The Glasgow Coma Scale is an assessment tool used to describe level of consciousness by evaluating eye opening, verbal response, and motor
response (Jones, 1979). Lastly, the Balance Error Scoring System is a postural stability test used to assess any balance deficits that may occur with a concussion.

The SCAT 2 is extremely thorough, which assists the medical professionals when making tough return to play decisions. However, this should not be the only type of test administered to note recovery of a concussion.

Computerized neurocognitive tests are also beneficial in assisting health care professionals when assessing and managing concussions. Some of the most common cognitive assessment tools are the Immediate Postconcussion Assessment and Cognitive Testing (ImPACT), Automated Neuropsychological Assessment Metrics (ANAM), CogSport, and Concussion Resolution Index (Guskiewicz et al., 2004). These computerized tests are beneficial and provide clinicians with more information to assist them in making accurate return to play decisions. However, they are expensive to use and many high schools cannot afford to spend money on this type of concussion tool. Those schools that cannot afford to use a computerized system for cognitive testing must rely on the Sport Concussion Assessment Tool (SCAT 2).

ImPACT is the most widely used and scientifically validated computerized neurocognitive assessment tool and was developed in the early 1990’s by Dr. Mark Lovell and Dr. Joseph Maroon (Lovell, Collins, & Bradley, 2004). The test takes approximately 20-minutes to administer and it measures multiple aspects of cognitive functioning including: “reaction time, verbal memory, visual memory, processing speed and impulse control” (Lovell, Collins, & Bradley, 2004, p. 436). Research suggests that self-reported symptoms following a concussion are much less sensitive than
neurocognitive testing and may result in premature return to play (Kampen, Lovell, Pardini, Collins, & Fu, 2006). Although, in a different study the results indicate that the higher and more symptoms the athlete reports following a concussion, the slower the reaction time based on the ImPACT (Lau, Lovell, Collins, Pardini, 2009). Therefore, the neurocognitive testing and symptom checklist should be utilized in conjunction when determining return to play decisions. There are many other reliable computerized neurocognitive tests, which are designed similarly to the ImPACT, however none are considered proven to be the primary way to evaluate concussions.

If a concussion is suspected and no medical professionals are available to provide care, it is recommended to remove the athlete from play and refer him/her to a physician’s office or emergency room for a follow up (McCrory, et al., 2008). A determination will then be made if neuroimaging is necessary. Typically, neuroimaging is normal in following a concussive injury, and therefore contributes little to a concussion evaluation (McCrory, et al., 2008). The disturbance of brain function is due to a dysfunction of brain metabolism rather than structural injury. The lack of published research on neuroimaging in regards to concussion limits the usefulness of these methods for diagnosing a concussion. Therefore, it is imperative that athletic trainers take a detailed concussion history during pre-participation examinations as well as at the time of injury.

In summary, the evaluation of concussions is a complex and multi-factorial process. Few objective signs and symptoms are displayed at the time of injury; therefore sports medicine professionals find assessment of a mild head injury quite difficult. Clinicians rely on a subjective report of symptoms given by the athlete. Unfortunately,
athletes tend to underreport their symptoms in fear that they will be held out of competition. The symptoms that they do report typically resolve quickly, yet underlying brain damage may still be present. For that reason, clinicians have been implementing the use of assessment tools for cognitive dysfunction (as mentioned above), as well as postural instability to detect deficits in brain function. As a result, baseline testing is recommended to establish the athlete’s pre-concussed normal performance. This will serve as a benchmark in the occurrence of concussion.

**Balance and Concussion**

Clinicians must also consider the effect of a concussion on motor control and postural stability. Literature has revealed that the areas of the brain affected most as a result of a mild head injury are responsible for equilibrium (Guskeiwicz, Riemann, Perrin, & Nashner, 1997). The outcome of many concussion studies indicate postural stability deficits on day 1 post-concussion with most individuals demonstrating balance recovery between day 1 and day 3 post-concussion (Guskiewicz et al., 1997; Guskiewicz, 2001; Guskiewicz, 2003, S. Slobounov, Cao, Sebastianelli, E. Slobounov, & Newell, 2007). In a different study, however, the subjects’ most noticeable balance deficits occurred during the first 24 hours, but appeared to resolve by day 5 (McCrea et al., 2003). Furthermore, there are some studies that detect postural abnormalities long after cerebral concussion in asymptomatic subjects as tested by other traditional concussion tools (Cavanaugh, Guskiewicz, Giuliani, Marshall, Mercer, & Stergiou, 2005; Slobounov et al., 2007).
Balance is defined as the “process of maintaining the center of gravity (COG) within the body’s base of support, and many factors enter into the task of controlling balance within the designated area” (Guskiewicz, 2001, p. 183). Assessing balance is an essential component to any neurological disorder. The body uses sensory and motor information to manage normal balance control (postural stability). The sensory process in balance involves an interaction between the somatosensory, visual, and vestibular systems (Shumway-Cook & Horak, 1986). The cerebellum is the most important center for controlling balance and posture. It receives information from the muscles, joints, skin, eyes, and ears (Guskiewicz, 2001). The eyes, the vestibular apparatus, and the proprioceptors are considered the postural reflexes. They transmit signals to the brain via afferent pathways. At which point, the brainstem and spinal cord send efferent signals to the skeletal muscles providing them with information to either increase or decrease tension (Guskiewicz, 2001). Patients with neurological problems have balance difficulties, due to an inapt interaction between the three sensory systems (Shumway-Cook & Horak, 1986). Research has shown that the preferred sense for balance control comes from the somatosensory information, but people generally rely on only one sense at a time for orientation (Guskiewicz, 2001).

Frequently, clinicians test postural stability after a concussion or mild head injury by instructing patients to perform balance skills with eyes-open, eyes-closed, on a stable surface, and on an unstable surface. This examines which sensory system is affected with the neurological condition they are experiencing. Research indicates that an increase in postural instability is reported when the patients are standing on a foam pad. The unstable surface eliminates the somatosensory component and suggests that the visual and
vestibular systems are not properly compensating for the loss of proprioception (Guskiewicz, 2001). Balance testing following an mTBI is another way that medical professionals can measure the seriousness of the head injury.

Balance Error Scoring System (BESS) is considered athletic trainers’ ‘gold standard’ when it comes to assessing postural instability following a concussion. The BESS test is made-up of six 20-second conditions. These include: double leg, single leg, and tandem stances on a solid surface with eyes closed, then repeated on a foam pad with eyes closed. The athlete is instructed to assume the required BESS stance by placing their hands on their iliac crests and keeping their head up and eyes closed (Onate, Beck, and Van Lunen, 2007). Counting the errors accumulated by the subject will score each of the 20-second trials. An error is described as any deviation from the stance. For example, moving hands off of the iliac crest, opening the eyes, step, stumble, or fall, abduction or flexion of the hip greater than 30 degrees, lifting the forefoot or heel off the testing surface, or remaining out of the proper testing stance for greater than 5 seconds (McCrory et al., 2009). Subjects that cannot perform the test for at least a minimum of 5 seconds are assigned the highest possible score for that particular condition. The BESS is a portable, cost effective, and quick way to assess static postural stability in the absence of sophisticated assessment tools.

There has also been considerable research conducted on the effectiveness of BESS and it appears to correlate well with other measures of postural stability. For example, in one research study done by Guskiewicz et al. the correlation connecting the Sensory Organization Test performed on the NeuroCom Smart Balance Master System with the BESS protocol was studied to determine the validity of the BESS (2001). It
showed that the subjects had postural deficiencies following concussion up to 3 days post-injury on both assessment tools (Guskiewicz, Ross, and Marshall, 2001). Therefore, we can assume that the BESS is as reliable as the SOT.

When examining the reliability of the BESS it is important to note the interrater and intrarater reliability. A study that was performed at the Mayo Clinic examined 30 individuals with three separate scorers. The subjects were video recorded and all three scorers graded thirty consecutive subjects individually. The scorers returned two weeks later, at which time they repeated the procedure. However, the videotaped subjects were viewed in randomized order. The interrater and intrarater reliability was estimated by calculating the inter- and intra-class correlation coefficients. The ICCs were reported with 95% confidence intervals.

The BESS intrarater reliability ICCs ranged from 0.50 - 0.88, while the interrater reliability ranged from 0.44-0.83 (Finnoff, Peterson, Hollman, & Smith, 2009). This particular study suggests that ICCs above 0.75 indicates good reliability, while those below 0.75 have poor to moderate reliability. “The intrarater reliability ICCs for all but two of the stances (single-leg and tandem stances on a foam pad) demonstrated ICCs greater than 0.75 (Finnoff, et al., 2009, p. 52).” Nonetheless, the total intrarater reliability ICC was 0.74. This suggests that only the single-leg firm-surface, tandem firm-surface, and double leg foam-surface may be valid postural stability measures when the same scorer is used for repeat testing. The interrater reliability ICCs for all but one of the stance positions were below 0.75 and the total was 0.57 (Finnoff, et al., 2009). The BESS single-leg firm surface is the only valid postural stability measurement when different scorers are used for repeat testing.
A study conducted by Reimann, Guskiewicz, and Shields the BESS interrater reliability ICCs were reported as 0.78 to 0.93 (1999). This study utilized 3 scorers all simultaneously scoring 18 subjects. The total BESS ICCs were not reported and the intrarater reliability was not assessed. Another study reported intrarater reliability ICCs of 0.87 to 0.98 for total BESS and BESS subscores based on the results of a single tester evaluating 20 different videotaped subjects (Valovich-McLeod, Perrin, Guskiewicz, & Shultz, 2004). The interrater reliability was not assessed.

The study previously mentioned by Finnoff, et al., in which both the interrater and intrarater reliability was examined showed much lower ICCs than the other two studies (2009). Many factors could have attributed to this, such as, a larger subject base, less skilled scorers, or the subjective nature of the BESS. Many of the errors are quite difficult to visually determine, in particular, the determination of when the leg moves into 30 degrees of hip abduction or when the subject makes multiple errors in quick succession. The BESS is a terrific on-field examination of postural stability, but has its flaws in regards to the lack of objectivity.

After an athlete is suspected of having sustained a head injury the BESS is typically administered the day of the injury or the day immediately following the injury. It is then given again once the athlete reports that all of his or her signs and symptoms have resolved. Some medical professionals may test more frequently, but the multiple testing could elicit a practice effect. A study done by Valovich, Perrin, and Gansneder proved that there is a significant learning effect when administering the BESS on day 1, day 3, day 5, and day 7 (2003). With repeated administration of the BESS the practice group showed significantly fewer errors from the first day of testing. The single-leg
stance and all of the foam surface stances showed the most improvements (Valovich, Perrin, & Gansneder, 2003). This is only one study among others that prove there are learning effects when administering a postural stability test in frequent succession. Clinicians need to be highly aware that multiple test exposures may lead to improved balance, which could mask concussion-related balance deficiencies.

The test-retest reliability of the BESS was examined in 2009, which suggested that the original BESS protocol had low to moderate intra-class and test-retest reliability ($r = 0.60, 0.67$), but a modified version of the BESS met the traditionally accepted thresholds for reliability measures (Hunt, Ferrara, Bornstein, & Baumgartner, 2009). The revised BESS protocol that proved more reliable only utilized four of the six stances. These were the single-leg and tandem-leg stance on the foam and firm surface. Another study by Valovich-McLeod, Barr, McCrea, and Guskiewicz (2006) revealed acceptable reliability ($r = 0.70$) for the BESS. This study examined fifty youth participants on two separate trials 60 days apart. The researchers believe that the significant improvement during the retest affected the reliability (Valovich-McLeod, 2006). Further research on the reliability of the BESS should be conducted to make sure that it is an accurate assessment of postural stability following a concussion.

Another method of assessing postural stability is the Biodex Balance System (BBS). However, limited normative data has been published on account of the program being less than two years old. The only study on this protocol was done through Biodex manufacturers. One hundred randomly recruited subjects were tested initially and then again 2 weeks later. A third test was administered after 3 months on just 27 of the subjects (Biodex Medical Systems, Inc., 2011). This data provided Biodex with the
normative sway index ranges for each m-CTSIB condition and resulted in an ICC of 0.81 (Biodex Medical Systems, Inc., 2011).

The Biodex utilizes the modified Clinical Test of Sensory Interaction and Balance (m-CTSIB). This test has been used to “systematically remove or conflict sensory input from one or more of the three senses” (Guskiewicz, 2001, p. 183). The traditional method incorporates a combination of three visual conditions, two support surface conditions, and three stances that add up to 18 separate trials when determining postural sway (Cohen, Blatchly & Gombash, 1993). Nevertheless, the m-CTSIB on the BBS is comprised of only one stance, two visual conditions, and two support surface conditions. The CTSIB is similar to the BESS protocol in that it can be utilized anywhere and it is cost effective. However, one advantage of the CTSIB over BESS is that many of the more sophisticated balance assessment equipment use the same protocol to test postural stability.

The BBS is used to objectively measure and record patients’ balance. It utilizes a dynamic multiaxial platform that is similar to the BAPS board when assessing dynamic balance (Guskiewicz & Perrin, 1996). In the past year Biodex has added a program to assess static postural stability, which is typically used to assess balance deficits following a concussion. The objective of this test is to quantitatively determine a subjects’ balance, which will define the patient’s ability to maintain a stable vertical posture while on a stationary platform. It does this by determining the overall sway index (OSI), which is the standard deviation of the stability index. The stability index is the average position from center and it does not determine how much the person swayed but how far they were from the center of the platform. The higher the OSI the more unstable the patient is
during the test. The OSI takes in to account the center of gravity (COG) in the anterior-posterior sagittal plane and the medial-lateral frontal plane (Biodex Medical Systems, Inc., 2011).

The benefit of testing postural stability on the BBS is that it can detect subtle balance deficiencies better than clinicians can with the naked eye during the BESS test. The disadvantage of the BBS is that the average clinician may not have access to it and it is quite expensive. Nonetheless, being that BBS has only recently added a concussion protocol to its system much more research is needed in order to prove its reliability and validity.

**Conclusion**

Concussions are one of the most difficult, but important injuries to evaluate. They can be life threatening or may produce long-term detrimental effects to the athlete if not taken seriously and properly managed. There are few objective signs that medical professionals can rely on; therefore clinicians need to be cognizant of subtle deficiencies that may occur to balance and neurocognitive functioning. More research is needed to determine effective methods of evaluating and determining return to play decisions following a concussion.
CHAPTER III

METHODS

This non-experimental design was used to assess test-retest reliability, as well as, determine if there was a relationship between the Balance Error Scoring System error scores and the overall sway index scores on the Biodex Balance System. The independent variable was the BESS protocol. The dependent variables were the overall stability index scores and the BESS error scores.

Participants

Thirty healthy subjects, 16 male (age = 23.8 ± 5.2 years, height = 70.2 ± 3.3 in, weight = 196.9 ± 58.5 lbs) and 14 female (age = 22.7 ± 2.5 years, height = 65.4 ± 2.5 in, weight = 141.1 ± 20.4 lbs) with no history of diagnosed concussion, vestibular disorders, or chronic illness were recruited through word of mouth or via email for this study. Subjects with lower extremity injury within the past six months were also not eligible to participate in this study. Informed consent was obtained prior to participation. This study was approved by Institutional Review Board at the University of Akron prior to beginning this study.
**Instruments**

The overall sway index was measured on the Biodex Balance System (Biodex Medical Systems, Inc., Shirley, NY, USA). The Biodex Balance System (BBS) was used to objectively measure and record patients’ balance. In the past year Biodex has added a program to assess static postural stability, which is typically used to assess balance deficits following a concussion. The objective of this test is to quantitatively determine a subjects’ score, which will define the ability to maintain a stable vertical posture while on a stationary platform. It does this by examining the overall sway index (OSI). The OSI is the standard deviation of the stability index. The stability index is the average position from center and it does not determine how much the subject swayed only their position on the platform. However, the higher the sway index the more unstable the patient is during the test. The OSI takes in to account the center of gravity (COG) in the anterior-posterior sagittal plane and the medial-lateral frontal plane (Biodex Medical Systems, Inc., 2011). The BBS uses the Clinical Test of Sensory Integration and Balance (CTSIB) for its standardized test protocol. However, this particular research study implemented and applied the Balance Error Scoring System (BESS) to the BBS.

Descriptive data of weight and height was collected and recorded using the digital scale (Doran Scales, Inc., Batavia, IL, USA) and the Dectecto Digital Stadiometer (Cardinal Scale Manufacturing, Co, Webb City, MO, USA).

**Research Design**

Prior to testing, participants read and signed a university approved informed consent and height and weight was recorded. All volunteers indicated that their balance
was unaffected by a lower extremity injury, vestibular disorder, chronic illness, and had no previous history of concussion.

Before placing any of the participants on the Biodex to perform the BESS protocol it was imperative to determine their dominant leg. To do this, we asked the subject which foot they would use to kick a ball. The foot they told us is considered the dominant leg. However, in accordance with the BESS protocol we then used their non-dominant leg for the purpose of this test.

Prior to testing, each subject was instructed to remove both shoes. Subjects were then asked to step onto the Biodex to complete the BESS protocol. Each participant was read the same script for instructions regarding body position and testing protocols. The test consisted of six 20-second trials with differing foot positions all with eyes closed. They were instructed to remain as still as possible and if they fall out of position they need to open their eyes; regain position and then continue until the 20 seconds is complete. For each stance the participant was instructed to position his or her feet so that the center of gravity is directly over the center of the platform.

The first stance was a double leg stance with feet together, eyes closed, and hands on the hips. The second stance was a single-leg stance, in which the subject performed the same test except they balanced on their non-dominant foot. The third stance was performed in the tandem position with the non-dominant foot behind the dominant foot. The fourth through sixth stances correspond to the first three stances. However, they were performed on a foam pad used to disturb the somatosensory information utilized in balance.
Each subject performed three separate trials with at least ten days between each trial to eliminate a learning curve. The participants were video recorded from the front view at a 45-degree angle for optimal visual examination for detecting errors. An error was described as any deviation from the stance. For example, moving hands off of the iliac crest, opening the eyes, step, stumble, or fall, abduction or flexion of the hip greater than 30 degrees, lifting the forefoot or heel off the testing surface, or remaining out of the proper testing stance for greater than 5 seconds (McCrory et al., 2009). Subjects that could not perform the test for at least a minimum of 5 seconds were assigned the highest possible score for that particular condition. The highest score for each stance is 10 errors; therefore the maximum score that can be given for the entire BESS protocol is 60. A qualified scorer evaluated all subjects on a later date, which allowed for repeated and precise scoring. Along with counting the errors, the overall sway index (OSI) was recorded on the BBS.

Each testing session lasted no more than a half hour. The qualified examiner chosen to score the BESS errors should have utilized this protocol for the use of teaching or in their own clinical experience. The researchers were re-educated prior to grading any of the subjects’ scores to ensure they have adequate knowledge of the test. The researcher recorded their scores on the BESS scorecard. The OSI scores were saved in the Biodex database and printed at the time of the test.

**Statistical Design**

Upon completion of the third testing session, results were analyzed to determine the test-retest reliability of the BESS on the BBS and determine if any significance was
found between the BESS error scores and the OSI scores. Pearson Product Moment Correlation was used to determine test-retest reliability of the BESS on the BBS and determine the relationship between the BESS scores and the OSI scores. Statistical significance was set \textit{a priori} at \( p < 0.01 \) and \( p < 0.05 \).
CHAPTER IV

RESULTS

The purpose of this investigation was to examine the test-retest reliability of the Balance Error Scoring System (BESS) on the Biodex Balance System (BBS) and to compare the Balance Error Scoring System (BESS) scores with the overall sway index (OSI) scores in apparently healthy adults between 18-40 years of age. Upon providing written consent and verbal agreement to the medical terms described in the methods section, 30 participants completed three testing sessions in the Athletic Training laboratory at the University of Akron. Participant characteristics are presented in Table 1.

Table 1. Participant Physical Characteristics

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age (Years)</th>
<th>Height (Inches)</th>
<th>Weight (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>22.7 ± 2.5</td>
<td>65.4 ± 2.5</td>
<td>141.1 ± 20.4</td>
</tr>
<tr>
<td>N = 14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>23.8 ± 5.2</td>
<td>70.2 ± 3.3</td>
<td>196.9 ± 58.5</td>
</tr>
<tr>
<td>N = 16</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pearson correlation analyses demonstrated there were moderate significant correlations between OSI 1 to OSI 2 (r = 0.589**), OSI 2 to OSI 3 (r = 0.648**), and OSI 1 to OSI 3 (r = 0.690**) at the p = .01 level. Correlation coefficients are presented in Table 2. Table 3 depicts significant correlations between BESS 1 to BESS 2 (r = 0.716**), BESS 2 to BESS 3 (r = 0.709**), and BESS 1 to BESS 3 (r = 0.900**). Again,
correlations were significant at the p = .01 level. Table 4 shows no significant correlation between BESS 1 to OSI 1 (r = 0.342), low to moderate significant correlation between BESS 2 to OSI 2 (r = 0.412* significant at p = .05 level) and moderate significant correlation between BESS 3 to OSI 3 (r = 0.603** significant at the p = .01 level).

Table 2. Pearson Product Moment Correlations between OSI trials.

<table>
<thead>
<tr>
<th>(M ± SD)</th>
<th>OSI 1</th>
<th>OSI 2</th>
<th>OSI 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSI 1 (14.8 ± 3.6)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSI 2 (13.7 ± 3.4)</td>
<td>0.589**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>OSI 3 (14.1 ± 2.7)</td>
<td>0.690**</td>
<td>0.648**</td>
<td>1</td>
</tr>
</tbody>
</table>

** p = 0.01

Note. Values are presented as mean ± SD. OSI 1 = overall sway index trial 1, OSI 2 = overall sway index trial 2, OSI 3 = overall sway index trial 3.
Table 3. Pearson Product Moment Correlations between BESS trials

<table>
<thead>
<tr>
<th>(M ± SD)</th>
<th>BESS 1</th>
<th>BESS 2</th>
<th>BESS 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>BESS 1 (11.1 ± 4.4)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BESS 2 (9.5 ± 3.8)</td>
<td>0.716**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>BESS 3 (10.4 ± 4.5)</td>
<td>0.900**</td>
<td>0.709**</td>
<td>1</td>
</tr>
</tbody>
</table>

** p = 0.01

Note. Values are presented as mean ± SD. BESS 1 = balance error scoring system trial 1, BESS 2 = balance error scoring system trial 2, and BESS 3 = balance error scoring system trial 3.

Table 4. Pearson Product Moment Correlations between BESS trials and OSI trials.

<table>
<thead>
<tr>
<th>(M ± SD)</th>
<th>OSI 1 (14.8 ± 3.6)</th>
<th>OSI 2 (13.7 ± 3.4)</th>
<th>OSI 3 (14.1 ± 2.7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BESS 1 (11.1 ± 4.4)</td>
<td>0.342</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BESS 2 (9.5 ± 3.8)</td>
<td></td>
<td>0.412*</td>
<td></td>
</tr>
<tr>
<td>BESS 3 (10.4 ± 4.5)</td>
<td></td>
<td></td>
<td>0.603**</td>
</tr>
</tbody>
</table>

** p = 0.01
* p = 0.05

Note. Values are represented as mean ± SD. BESS 1 = balance error scoring system trial 1, BESS 2 = balance error scoring system trial 2, BESS 3 = balance error scoring system trial 3, OSI 1 = overall sway index trial 1, OSI 2 = overall sway index trial 2, and OSI 3 = overall sway index trial 3.
Postural stability assessment has been recognized as an important component of evaluation after a concussion. The 3rd International Conference on Concussion in Sport states that “postural stability testing provides a useful tool for objectively assessing the motor domain of neurologic functioning, and should be considered a reliable and valid addition to the assessment of athletes suffering from concussion” (McCrory, et al., 2008, p. 38). The Balance Error Scoring System (BESS) is the traditional method used by sports medicine physicians to determine balance deficiencies following a concussion. It was initially developed to be a cost-effective, portable, and objective assessment tool used by clinicians for the evaluation of postural stability following a concussion. However, past research has shown conflicting interrater reliability, moderate test-retest reliability, and significant practice effects (Finnoff, et al., 2009; Hunt, et al., 2009; & Valovich, Perrin, & Gansneder, 2003). To our knowledge, this is the first study to investigate the BESS protocol on the Biodex Balance System in order to determine if there is similar reliability in comparison to the established BESS protocol. Therefore, the purpose of the present study was to examine the test-retest reliability of the BESS on the BBS and to determine the relationship between the BESS scores and the OSI scores.

The results of the present study indicate that the BESS error scores while on the BBS showed moderate to high, significant correlations of \( r = 0.71, r = 0.71, \) and \( r = 0.90 \) for all three trials in comparison to the OSI correlations of \( r = 0.59, r = 0.65, \) and \( r = 0.86 \).
= 0.69). To date only three studies have examined test-retest reliability showing similar correlations, which are in agreement with the present study when looking at the error scores (Broglio, Zhu, Sopiarz, & Park, 2009; Hunt, et al., 2009, & Valovich-McLeod, Barr, McCrea, & Guskiewicz, 2006).

In the study by Hunt et al. (2009) they found a moderate correlation of \((r = 0.60)\) when testing 78 high school football athletes, which is in accordance with the results from the present study. The researchers examined correlations of one trial involving all six conditions, however, the present study examined three separate trials involving all six conditions on the BBS and test results revealed higher correlations overall. This suggests that when the individual performs more trials the reliability may increase.

In the same study performed by Hunt et al. (2009) they removed the double leg stance on the foam pad and on the solid surface and had subjects perform the remaining four conditions. They found that reliability increased from \((r = 0.60\) to \(r = 0.71\)). Both double leg stances show little variance between subjects and poor sensitivity during baseline testing and postinjury evaluation, therefore, this study suggests that the double leg stance could be eliminated. It also revealed that as the number of trials increased using the four conditions so did the reliability. For example, when participants performed 3 trials of the modified BESS the correlation was \(r = 0.84\) (Hunt et al., 2009). That being the case, the reliability of the modified BESS is similar to the present study findings. However, a possible limitation of their study was that all subjects performed three trials of four conditions in the same day, which suggests a practice effect. In order to control for a practice effect researchers suggested that the first trial be used as a practice trial.
The second study that examined test-retest reliability by Broglio et al. (2009) showed overall reliability of the BESS was $G = 0.64$. It was improved when male (0.92) and female (0.91) participants were examined independently. This study is similar to Hunt’s modified BESS research, because each subject performed multiple trials in one day. Also, the study results show that reliability of the BESS improved as the number of trials administered increased (Broglio et al., 2009). Three administrations of the BESS testing provided acceptable reliability. For that reason, this study and the modified BESS study performed by Hunt et al. (2009) suggest that the BESS test be administered at least three times in a row and then take the mean of each stance to have the most reliable postural stability test.

The third study of test-retest reliability conducted by Valovich-McLeod, et al. (2006) had similar procedures to the present study. They examined the BESS test on 50 youth subjects on two separate trials and found acceptable reliability ($r = 0.70$). Even though this study had a much longer time between trials compared to the present study they found significant improvements during the retest that could have affected the reliability.

In the present investigation at least ten days separated each of the three trials to diminish the possible learning effect. The goal was to investigate the traditional six-condition protocol, not the modified BESS, on the BBS during three different testing sessions to compare error scores and sway index scores within and between each other. We can then hypothesize that if both the errors scores and the sway index scores showed high correlations then perhaps the BESS protocol on the BBS is just as effective or more effective than the traditional BESS on land. However, more research should be
performed using the modified BESS in comparison to the standard BESS, because results have been shown to be inconclusive.

Additionally, the present study examined the OSI scores on the BBS, but exhibited much lower correlations between the three trials compared to the error scores of the BESS. No known research has been done using the BESS protocol on the BBS; consequently it is difficult to determine the reason for the lack of reliability that was found. Perhaps, the BBS machine was overly sensitive to the larger errors that each participant made, especially during the single leg and tandem stances. At times, subjects would put their foot down on the platform to reestablish balance or even step completely off the platform during the test. If the athlete stepped off the platform the error is not even being calculated. To accurately measure sway the platform would have to be much larger.

Typically, the BBS is used to assess sway during static balance testing. Sway is the distribution or movement of the center of gravity over the base of support and is deployed without thought to help the body stay on balance. The m-CTSIB is the protocol used on the BBS for concussed athletes. During the m-CTSIB protocol the participant stands on two feet for the entire testing and typically does not fall out of position. Therefore, sway can be accurately detected. However, when using the BESS protocol on the BBS the subjects tended to fall out of position during the single leg stances and tandem stances, which led to extreme variance in the overall sway index per stance and individual. This may explain the possible low correlations observed in the present study.

Finally, when examining the relationship between the OSI scores and the BESS scores for each trial we found significant correlations (p < .05 and p < .01) between trial 2 to trial 3 and trial 1 to trial 3, respectively. However, they are considered, at best, low to
moderate correlations. These correlation scores are in accordance to those from one study conducted by Reimann, Gruskiewicz, and Shields (1999). The purpose of that study was to examine the extent to which the error scores correlate with objective sway measurements found on a forceplate. The researchers found no correlation with the double leg stance on a firm surface, but found significant correlations for all of the foam stances, as well as, the tandem and single leg solid surface stances (Reimann, et al., 1999). The present study did not look at individual stances, but instead studied the overall error scores and OSI scores of all subjects to determine test-retest reliability. Nonetheless, it is still assumed that if the error scores increased and the OSI scores increased they would display a significant correlation. Another reason for the low correlations could be due to the way in which errors are measured with BESS compared to the objective sway measurements of the BBS. It is possible that the BBS measures small errors much better than large errors and the BESS does not discriminate between the magnitude of errors. For example, even the slightest of errors, such as, opening of the eyes is given a score of one error.

Limitations

We acknowledge that certain limitations exist in this investigation. It is important to note that during the second trial of this study the BBS had mechanical complications. The platform stability was not accurately calibrated. Therefore, many of the OSI scores from trial two on the BBS may not be accurate. However, when examining the data between and within the OSI scores and the BESS scores of trial one and trial three better correlations were found. This suggests that there may have been even higher correlations if the platform was calibrated correctly for each trial and in no way negates the
significant results found in this study.

We identified that the BESS error scores showed similar reliability to previous studies and the OSI scores showed significance, but with low to moderate correlations. In addition, the correlation between the BESS error scores and the OSI scores revealed the lowest correlations. Based on previous research and the current study, the subject number was much too low and perhaps with a larger sample size the data would have been more conclusive. Another limitation of the present study was that the data was collected on apparently healthy individuals, not concussed athletes. Future research is warranted to address these issues and to potentially find more significant results supporting the use of the BBS.

Clinical Relevance

Measuring an athlete’s postural stability following a concussion is useful when trying to make proper return to play decisions and to determine the severity of the concussion. This is merely one aspect medical professionals pay particular attention to when a suspected head injury has occurred. Recently, it has been demonstrated that concussion affects the areas of the brain that are responsible for the maintenance of postural stability (Riemann and Guskiewicz, 2002). The major purpose of this study was to examine the extent to which tester error scores correlate with objective biodex sway measures and to see if the BESS on the BBS is a reliable measurement tool for assessing postural stability. We hypothesized that the BBS would add increased objectivity and sensitivity to the more subjective error scores. However, the results found in the present study are inconclusive and further research is needed to determine if the BBS is a reliable
tool for detecting postural stability deficits following a concussion. From the results found in this study it seems as if the BESS should continue to be utilized as the ‘gold standard’ when evaluating the balance of concussed athletes, however, clinicians should be wary of the possible practice affects associated with the BESS test.

Future Directions

1. Further research should include concussed athletes to see if BESS error scores and OSI scores yield similar results.

2. Further research should eliminate the double leg stances for the BESS and compare it to the traditional BESS on the BBS to see if significant correlations are found.

3. Further research should be conducted utilizing the present study’s methods, except on a much larger sample size to see if it may yield similar or better results.

4. Further research should compare the BESS protocol on the BBS to other methods of balance assessment.

5. Further research should compare the m-CTSIB protocol to the BESS protocol on land and on the BBS.

6. Further research should examine the test-retest reliability focusing on the individual BESS stances, while on the BBS.
REFERENCES


Biodex Medical Systems, Inc, Addendum to Biodex Balance SD, Software upgrade version 1.32 release notes, CTSIB Test Inclusion.


Center for Disease Control Home, Non-fatal traumatic brain injuries from sport and recreation activities. (2007). Retrieved from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5629a2.htm


36


APPENDIX A

INFORMED CONSENT FORM
**Title of Study:**  Validity and reliability of the Balance Error Scoring System on the Biodex Balance System.

**Introduction:** You are invited to participate in a research project being conducted by Kristin Knapp a graduate student enrolled in the exercise physiology program at The University of Akron, under the advisement of Carrie Fister, MEd, ATC/L, faculty member at The University of Akron in the Department of Sport Science and Wellness Education.

**Purpose:** The purpose of this study is to validate the Biodex Balance System as an objective and reliable tool for concussion assessment.

**Procedure:** If you volunteer for this study, you will be required to take part in three testing sessions. Each testing session will take approximately 30 minutes, with no less than ten days between testing sessions. During the first session, the testing protocol will be explained and any questions you have will be answered. The investigator will then measure and record your weight and height. Next, you will be asked to perform the Balance Error Scoring System protocol on the Biodex Balance System. The BESS protocol consists of six, twenty-second balance trials all with eyes closed. You will be asked to balance on two feet, one foot, and in a tandem stance. The first three trials will be done on a solid surface and the last three trials will be done on a foam surface. All trials will be video recorded for later error scoring. The overall sway index of each stance will be recorded, printed, and saved using the biodex balance system.

**Risk and Discomfort:** None

**Benefits:** By participating in this study, the subject will be able to learn more about their own postural stability and/or balance deficits. They may also help provide great insight into the management of concussions and proper return to play decisions based on postural stability.
Payments for Participation: There will be no payment for participation.

Right to refuse or withdraw: You may withdraw from the study at any time. There is no penalty if you decide to withdraw.

Confidential Data Collection: The data collected in this study will be coded. Data will be password protected and stored/accessed electronically only by the study investigators. Any hardcopy form of data, such as measurement print-outs, will be stored in a locked cabinet in InfoCision Stadium, 307G. Only the study investigators have access to this information.

Confidentiality of records: Your records will be password protected and stored/accessed electronically only by the study investigators. Any hardcopy form of your records will be stored in a locked cabinet in InfoCision Stadium, 307G. Only the study investigators have access to this information. If you agree to have your information used as part of the research data, you will be asked to sign this informed consent document.

Who to contact with questions: If you have any questions at any time, you may contact any of the following:

Kristin Knapp 330-472-1441 kmk5@zips.uakron.edu

Carrie Fister, MEd, ATC/L Research Advisor 330-972-8499 fister@uakron.edu

This study has been reviewed and approved by The University of Akron Institutional Review Board (IRB). If you have any questions about your rights as a research participant, you may call the IRB at (330) 972-7666.

I have read the information provided above and all of my questions have been answered. I voluntarily agree to participate in this study. I will receive a copy of this consent form for my records.
Participant Signature: ___________________________    Date:___________________

Witness: ___________________________    Date: ___________________
APPENDIX B

BESS SCRIPT
BESS Script

Direction to the subject: I am now going to test your balance.

Please take your shoes off, roll up your pant legs above ankle (if applicable).

This test will consist of 6-twenty second tests with three different stances on two different surfaces on the Biodex Balance System. I will describe the stances as we go along.

Double Leg Stance:

Direction to the subjects: The first stance is standing with your feet like this (administrator demonstrates two-legged stance).

You will be standing with your hands on your hips with your eyes closed. You should try to maintain stability in that position for entire 20 seconds. I will be video recording each stance, so that later I can go back and correctly count the number of times you move out of this position. For example: if you take your hands off your hips, open your eyes, take a step, lift your toes or your heels. If you do move out of the testing stance, simply open your eyes, regain your balance, get back into the testing position as quickly as possible, and close your eyes again.

I will be positioned by you to help you get into the testing stance and to help if you lose your balance.

Direction to the subject: Step up on to the Biodex platform and position your feet together and hands on your hips. Look at the screen in front of you and try to put the cursor as close to the center point as possible, while maintaining balance. You may need to move your feet forward or backward to get a comfortable and proper stance. (This should only take a couple of seconds). Now that we have the foot position set the testing is ready to begin. When you are ready close your eyes and I will begin the test.


**Single Leg Stance:**

**Direction to the subject:** *If you were to kick a ball, which foot would you use?* (This will be the dominant foot).

*Now stand on your non-dominant foot in the middle of the platform and use the screen in front of you to position the cursor as close to the center point as possible. (administrator will assess the position of the dominant leg as such: the dominant leg should be held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion)* *You may need to move your feet to achieve the correct and comfortable position.*

*Again, you should try to maintain stability for 20 seconds with your eyes closed.*

*Place your hands on your hips. When you close your eyes the testing time will begin.*

**Direction to the spotter:** *You are to assist the subject if they fall during the test and to help them get back into the position.*

**Tandem Stance:**

**Directions to the subject:** *Now stand heel-to-toe with your non-dominant foot in back (administrator may need to demonstrate the stance). Your weight should be evenly distributed across both feet. Again, use the screen in front of you to position the cursor as close to the center point as possible.*

*Place your hands on your hips. When you close your eyes the testing time will begin.*

**Direction to the spotter:** *You are to assist the subject if they fall during the test and to help them get back into the position.*

*** Repeat each set of instructions for the foam pad.***
APPENDIX C

HUMAN SUBJECTS APPROVAL FORM
NOTICE OF APPROVAL

January 30, 2013

Kathryn Amsen
216 North Pantego Pkwy, Apt. 103
Alamo, CA 94501

From:  Sharon McWhorter, IRB Administrator

Re:  IRB Number 2012-0106 "Validity and Feasibility of the MRIA Protocol on the Bladder Balance System"

Thank you for submitting an IRB Application for review of Research Involving Human Subjects for the referenced project. Your protocol represents minimal risk to subjects and has been approved under Expected Category 1A.

Approval Date: January 29, 2013
Expiration Date: January 29, 2014
Continuation Application Due: January 15, 2014

In addition, the following have been approved:

- Waiver of documentation of consent
- Waiver of attention of consent
- Recruit: Involving children
- Research involving prisoners

Please adhere to the following IRB policies:

- IRB approval is given for not more than 12 months, if your project will be active for longer than one year, it is your responsibility to submit a continuation application prior to the expiration date. We request submission two weeks prior to expiration to ensure sufficient time for review.
- A copy of the approved consent form must be submitted with any continuation application.
- If you plan to make any changes to the approved protocol you must submit a continuation application for change and it must be approved by the IRB before being implemented.
- Any adverse reactions/ incidents must be reported immediately to the IRB.
- If this research is being conducted for a master's thesis or doctoral dissertation, you must file a copy of this letter with the thesis or dissertation.
- When your project terminates you must submit a Final Report Form in order to close your IRB file.

Additional information and all IRB forms can be accessed on the IRB website at: http://www.uakron.edu/osp/osp/consumer/irbforms.php

Cc:  Randi Dinnocente - Advisor
Cc:  Valerie Catalani - IRB Chair

[Signature]

Office of Research Services and Sponsored Programs
The University of Akron, Office of Research Services and Sponsored Programs