MEASUREMENT OF VALIDITY FOR BALANCE ASSESSMENTS USING A MODIFIED CTSIB SWAY INDEX VERSUS A BIODEX SWAY INDEX

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MEASUREMENT OF VALIDITY FOR BALANCE ASSESSMENTS USING A
MODIFIED CTSIB SWAY INDEX VERSUS A BIODEX SWAY INDEX

Jody Duecker

Thesis

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CHAPTER I
INTRODUCTION

Athletics and physical activity plays a large role in today’s youth, high school, and college programs. There are many occurrences of injury and concussions in the realm of athletics and physical activity. Athletes that compete in a collision sport are at a higher risk for obtaining a concussion than those involved in sports with less contact. Over the last decade, there has been much controversy regarding head injuries leading to concussions, the Centers for Disease Control and Prevention (2013) reports an estimated 1.7 million traumatic brain injuries (TBI) annually in the United States. Often times there are many concussions that were not reported due to lack of symptoms, risks, or education of concussion. Langlois et al. (2006) reports an estimated 1.6-3.8 million sports related concussions annually in the United States.

In most circumstances a concussion can occur if the head hits an object or an object hits the head, but impact is not always the cause (Evans, 2011). There are many signs and symptoms associated with a concussion, and the signs and symptoms vary among individuals but neurological deficits are commonly expected with a concussion such as loss of memory or confusion, but growing research has provided us with data that supports postural instability or
loss of balance as one of the main symptoms associated with concussions (Biodex, 2013).

Even though currently, there are multiple assessment tools and guidelines for the diagnosis of a concussion, most of these current guidelines do not consider the effects a TBI has on postural stability (Guskiewicz, 2001). Most balance tests are subjective in nature and vary from clinician to clinician. The Balance Error Scoring System (BESS) and modified-Clinical Test of Sensory Interaction and Balance (m-CTSIB) both offer a thorough balance assessment providing a count of errors from the clinician or gives a description of swayed or does not sway, but both tests are subjective in nature (Maranao-Filho et al., 2011). In order to further decrease the chances of serious injury following a traumatic brain injury, proper objective assessment tools must be utilized by physicians and athletic trainers.

Continued research on assessment and return to play criteria are an integral component for concussion management. It is hypothesized that there will be significance in the sway index scores of the m-CTSIB and BBS. The purpose and hope of this study is to validate the m-CTSIB protocol on the BBS as an objective and reliable tool to assess balance. Specifically, this research aims to answer the following questions:

1. Is there a significant difference in stability index scores when comparing different stances among different trials?
2. Is there a significant difference between overall stability index scores when comparing between trials?

3. What is the test-retest reliability of the m-CTSIB protocol on the BBS?

4. Is there a correlation of stability index scores of the four stances between trials?

5. Is there a correlation between the traditional m-CTSIB protocol scores (measured by time held in testing position seconds) and the m-CTSIB scores as measured by the BBS (measured by overall stability index)?
Concussions are an issue that seems to come up over and over again in athletics, but it truly is a safety concern. It is estimated that 5-10 percent of athletes will experience a concussion in any given sport season and fewer than 10 percent of sport related concussions involve a loss of consciousness (LOC) (Sports Concussion Institute, 2012) There is on going controversy about what defines a concussion. Prior to 2001 an assessment and grading scale system was the main consideration in the severity of the concussion (Hunt & Asplund, 2010). It was previously thought that a loss of consciousness posed a higher threat of serious injury and longer healing times, however individuals without a loss of consciousness presenting various signs and symptoms can have prolonged symptoms just as long as athletes with a loss of consciousness (Barton & Meehan, III, 2011).

The National Athletic Trainer’s Position Statement on concussions indicates that there are three approaches used in analyzing a concussion, the first is grading the concussion at the time of injury, the second, deferring the grading until all symptoms have resolved, and the third, includes no use of a scale but an interactive approach that focus’s attention on the recovery of symptoms, neurocognitive testing, and postural stability testing (Guskiewicz et al., 2004).
The definition of a concussion has been altered many times to properly include the wide range of characteristics that may occur following a traumatic brain injury (TBI). Still today, various definitions of a concussion exist. According to Guskiewicz et al. (2004) a concussion is a traumatic brain injury that may result in a headache, altered levels of alertness, and unconsciousness. It can affect many areas of the brain causing problems with memory, reflexes, speech, balance, coordination, and sleep patterns.

Adjustments were especially considered after eliminating the grading system. Therefore, in the Consensus Statement on Concussion in Sport: the 3rd International Conference on Concussion in Sport Held in Zurich, November 2008, a concussion or mild traumatic brain injury is described as a “complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces” (McCrory et al., 2009). This definition of concussion offers insight into the various signs and symptoms that can be caused from a concussion, some of which include impaired cognitive functions, such as confusion, amnesia, loss of consciousness, slow reaction time, lack of visual acuity, hearing problems, slowness, fatigue, and the sense of pressure or heaviness in the head. Other common signs and symptoms include but are not limited to headache, dizziness, loss of balance, emotional reactions, seizure, vomiting, and poor concentration (Wilson, 2011).

There are multiple tools available that Certified Athletic Trainers (AT) use to examine concussions. Ninety-five percent of AT’s utilize a clinical examination,
85% used a symptom checklist, and 48% used the Standardized Assessment of Concussions (SAC) (Notebaert & Guskiewcz 2005). The SAC includes measures of orientation, immediate memory, concentration, and delayed recall as well as a brief neurological assessment of coordination, recall of the event, and performance of sport specific exertional activities (Peterson, 2002). Sixteen percent of AT’s that used the BESS as a balance assessment proposed the BESS should be used as an alternative balance assessment technique for concussions (Notebaert & Guskiewcz 2005). Eighteen percent of AT’s used neuro-psychological testing for a portion of their concussion evaluation (Notebaert & Guskiewcz 2005). Neuropsychological tests offer insight into speed and flexibility of cognitive functioning, memory, and attention (Hunt & Asplund, 2010).

Another reason grading scales have been reduced is the thought that athletes, coaches, healthcare professions, and even physicians have not considered grade 1 and 2 concussions to be severe and players have often returned to play too early making them more susceptible to greater injury (Catena & van Donkelarr, 2006). If an athlete returns to play with continued symptoms following a concussion, the chances of the athlete having decreases in motor deficits, lack of muscular strength, and uncoordinated movement can leave an athlete more susceptible to another head injury (Catena & van Donkelarr, 2006).

A second concussion or repeat TBI before the first one resolves is known as second impact syndrome (SIS). Guskiewicz (2004) defines second impact...
syndrome in the National Athletic Trainer’s Association (NATA) position statement on concussions as “when an athlete is susceptible to a blow following their initial brain injury causing a rapid increase in intracranial swelling, which may lead to death”.

SIS can have cumulative effects on the neurocognitive functions of the brain, which can cause death, permanently alter performance, and cause behavioral changes (Wilson, 2011). This is just an additional reason why current return to play (RTP) protocols following concussions are just as important as the diagnosis and treatment. Each concussion is as different as the individual it affects, the various signs and symptoms vary case to case. Current RTP protocols are based on the athlete’s readiness for return based on symptoms. Recent guidelines in sports medicine suggest the athlete have zero cognitive symptoms before participation. A RTP paradigm for activity can be seen in Appendices E (Hunt & Asplund, 2010).

Concussions not only can have an impact on cognitive function but also balance capability. One of the main components of the return to play assessment is the postural stability assessment of the athlete following a concussion (Hunt et al., 2009). There are three components that are shown to aid in postural stability. Maintaining balance requires the aid of visual, somatosensory muscular coordination (proprioceptive), and the sensory organization of vestibular sensations (Guskiewicz, 2001). Balance deficits following a concussion can exist weeks and in some cases months after the
initial injury. There have been correlations with postural sway and concussions in patients immediately after injury and usually up to 7 days post injury to pre injury baseline values (Hunt, 2009). Postural sway and instability are attributed to the center of gravity (COG) in the body and balance is the process of maintaining the center of gravity within the body’s base of support (Hunt, 2009). Research has shown that an unstable surface decreases or eliminates the somatosensory component for the loss of proprioception (Guskiewicz, 2001).

There are several tools that are regularly used by athletic trainers and physicians for balance assessment. For concussions, the current gold standard in assessing postural stability is the Balance Error Scoring System, also known as the BESS. This protocol uses not only static balance conditions but also dynamic conditions (Cachupe et al., 2001). The BESS was initially developed and utilized for measuring postural stability for concussion assessment (Hunt et al., 2009). Considerable research has been conducted using the BESS and it has shown to correlate with other measures of postural stability such as the Sensory Organization Test (SOT) (Hunt et al., 2009).

The BESS test requires subjects to stand as steady as possible during three different variations of the Romberg test (double leg, single leg, and tandem stance) both on a firm surface and a foam surface, as AT’s count the number of errors occurring during each 20-second trial (Riemann & Guskiewicz, 2000). An error occurred if the subject lifted their hands off their hips, opened their eyes,
took a step, or fell out of the testing position (Riemann & Guskiewicz, 2000). The test is cost effective and a measurement tool for sensitivity of injury to neurological deficits. This system examines which sensory areas are affected and whether or not they may be experiencing a neurological deficit from a concussion by allowing the three components to be tested individually (Onate et al, 2007).

The SOT uses a forceplate system that measures vertical ground reaction forces produced by the body’s center of gravity moving around a fixed base of support (Guskiewicz et al., 2001). The SOT is designed to systematically disrupt the sensory selection process by altering available somatosensory or visual information or both while measuring a subject’s ability to minimize postural sway. The test protocol consists of 6 conditions performed 3 times each for 18 total trials, 20 seconds each, in which the subject is asked to stand as motionless as possible with the feet shoulder-width apart. Subjects stand on a firm surface for a double leg stance, single leg and tandem stance and then each stance is performed again on a foam surface. This is a measurement that calculates sway and is used for vestibular and fall risk assessment (Guskiewicz et al., 2001). The SOT has shown to be a valid tool for measuring balance deficits (Guskiewicz & Register-Mihalik, 2011).

The m-CTSIB test was invented in 1986 by physical therapist’s Shumway-Cook and Horak to originally develop fall risk assessments for older adults and
rehabilitation guidelines for balance deficits and lower extremity injuries. This test is very similar to the BESS, but it is mostly used in clinics to measure the center of mass in the body (Guskiewicz, 2001).

The m-CTSIB test has changed over the years to include four conditions that test static stability and dynamic stability utilizing a foam pad. Originally the CTSIB was a test offering six conditions. Two stances that used a visual conflict dome were eliminated due to the fact that it had minimal effect versus the closed eye condition (Peterson, 2002). The stances are listed in Appendices F. Weber (1993) found that the m-CTSIB shows “a high degree of concordance (90%) with the SOT” and Suttanon (2006) found the reliability of the test has been proven against forceplate measurements.

The three indicators of motor function that may be impaired from a concussion (visual, somatosensory, and vestibular) can be tested using the m-CTSIB. This test inhibits these senses in the body allowing them to be tested separately. The separate conditions show which senses may be compromised following a concussion (Yim-Chiplis & Talbot, 2000). The trial time should be stopped when a person deviates from the initial crossed arm position, opens their eyes in a closed condition, patients moves feet or takes a step, or requires assistance from the clinician to prevent falling. A trial is successful if the patient is capable of maintaining the starting position independently for a period of 30 seconds. A maximum of three trials are performed for all conditions. Trials are
performed until the patient either successfully maintains the starting position for entire 30-seconds, or completes three, 30-second trials to the best of their ability (Shumway-Cook & Horak 1986).

The sway index is an objective quantification of the standard deviation of the athlete’s average position from the center. So the higher the sway index the more unsteady or less balanced the person was during the test. This sway index is either based the clinician’s opinion of how well the subject was able to balance during the m-CTSIB. This is done by assigning a value of 1 to 4 to characterize the sway. 1 = minimal, 2 = sway, 4 = a fall (Edwards & Peterson, 2011). Or the sway index can be calculated for the m-CTSIB by adding the time for each stance for a maximum total of 120 seconds.

Measurements of CoM have been found to provide better insight into dynamic balance control mechanisms and cognitive functions (Catena & van Donkelarr, 2006). The use of the Biodex Balance System (BBS) offers objective balance measurements to athletic trainers and physicians. This system is a tool for assessing postural stability and neurologic function following a concussion. It calculates not only sway index but also stability index. The stability index is a measurement of the average position from the center (BBS, Biodex Medical Systems, Inc, 1999). The BBS is multi-axial device that objectively measures and records an individual’s ability to stabilize the involved joint under dynamic stress (BBS, Biodex Medical Systems, Inc, 1999). The platform which has parameters
that can be set to static or dynamic move anteriorly, posteriorly, medial and lateral and calculates an overall stability index and sway index based on foot position and center of mass (CoM) (BBS, Biodex Medical Systems, Inc, 1999). The sway and stability indexes represent fluctuations around a zero point established prior to testing when the platform is stable (Arnold&Schmitz, 1998).

The Biodex Medical Systems, Inc has built the m-CTSIB protocol directly into their BBS. Biodex conducted a research study to measure the reliability of the m-CTSIB utilizing the BBS. The study included 20 male and female participants. Results also appear in Appendices G. Normative Sway Index ranges are for Stance 1: Eyes Open firm surface: .21-.48, Stance 2: Eyes closed firm surface: .48-.99, Stance 3: Eyes Open foam surface: .38-.71, Stance 4: Eyes Closed foam surface: 1.07-2.22 (Biodex Medical Systems, Inc.). These results offer a baseline for the m-CTSIB protocol on the BBS (Biodex Medical Systems, Inc.).

The m-CTSIB protocol has recently been used and studied for return to play concussion protocols. This postural test provides an objective measurement rather than a subjective assessment. The current balance assessment such as BESS are based on subjective assessments. The stability index and sway index defined in the previous section are objective measurements calculated by the BBS. These calculations offer insight into the balance associated with pre concussed athletes and post concussed athletes. Utilizing the BBS as an
assessment tool in addition to cognitive testing can help physicians and athletic trainers with return to play guidelines and protocols.

It is important to note that the BBS has the capability of modifying a protocol and adding steps, so the protocol for the BBS can include stances such as the m-CTSIB on the BBS or stances such as one foot with eyes closed and foam surface (Suttanon, 2006). Although there have been positive outcomes of the m-CTSIB on the BBS as a fall risk assessment and as a balance test, there are currently no studies that investigate the m-CTSIB protocol on the BBS as a means of concussion management (Biodex Medical Systems, Inc.). Further studies are needed to validate the m-CTSIB in order to evaluate its potential use in concussion management.
CHAPTER III

METHODS

Participants: The study was approved by the University of Akron’s Institutional Review Board for the protection of human subjects (Appendix A) and consisted of both males (n= 14), and females, (n = 16), aged 18 – 47. Participants were volunteers who were recruited from The University of Akron's Department of Sport Science and Wellness program through email. Each participant read and agreed to the consent form to participate. The first 30 people to respond and meet all eligibility requirements were accepted for participation. Participants were eligible if they were between the ages of 18-49, had no vestibular disorders, taking no medications for dizziness, no previous concussion within 6 months of testing, and no current lower leg injury. Descriptive data for all participants is shown in Table 1.

Program Design: Balance was measured using the Biodex Balance System, SD. Before each test session the subjects were asked various exclusion criteria questions (Appendix C). Testing consisted of 4 separate stances performed four times each. Each individual returned to perform the exact same protocol two more times at least 7 days apart each time. The participant had his/her shoes off for each measurement, feet placed comfortably
so their weight was centered, hands placed on opposite shoulders, and the script was read each time to ensure reliability. The examiner timed the individual with a stopwatch as if the participant was performing the action without the use of the Biodex. This way the m-CTSIB was only conducted one time for each stance. The participant did not use a blindfold for this protocol for eyes closed stances.

The Biodex Balance System (BBS), which uses the m-CTSIB protocol includes four tests (Appendix F). They all use a double leg stance with eyes open and then eyes closed on a solid surface and then on an unstable surface holding each for 30 seconds (1) Eyes open, firm surface, (2) eyes closed, firm surface, (3) eyes open, foam surface, and (4) eyes closed, foam surface (Suttanon, 2006). Taking a step, moving the hands from the shoulders, or opening the eyes was cause for the clock to be stopped. The modified CTSIB was measured and evaluated by a clinician using the scoring system based on the time the participant was able to hold each pose up to thirty seconds each. The time of each stance is added up for a maximum total of 120 seconds and then the scores are averaged (Hart-Hughes & Haley, 2010).

**Statistical Design:** The statistical analysis was performed using a Pearson Product Moment Correlation to determine the correlation between the traditional m-CTSIB scores and BBS m-CTSIB scores. A Pearson Product Moment Correlation was also used to determine the correlation of overall stability index between trials as well as the stability index for each individual stance among the
trials. A paired sample t-test was used to determine the difference between trial two and trial three overall sway indexes as well as the difference between stability index scores of each individual stance between trials. The a priori level was set at $p < 0.05$. Due to a calibration error on the Biodex Balance System during trial one, only trial two and three data was considered when reporting the results. Results of the study were based on thirty participants (n=30).
CHAPTER IV

RESULTS

The purpose of the present investigation was to examine the reliability of the modified-Clinical Test of Sensory Interaction and Balance (m-CTSIB) on the Biodex Balance System (BBS) and compare the sway indexes of Trial two with Trial three sway indexes in apparently healthy adults between 18-49 years of age. Trial 1 data was not used due to inconsistencies in the BBS equipment. Upon providing written consent and verbal agreement to the terms described in the methods section thirty participants completed the investigation, males (n=14), females (n=16). 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>25.3±7.0</td>
<td>65.9± 2.4</td>
<td>150 ± 17.6</td>
</tr>
<tr>
<td>N = 16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>23.0 ± 5.9</td>
<td>69.8 ± 2.5</td>
<td>205.1 ± 54.6</td>
</tr>
<tr>
<td>N = 14</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
The results of the Pearson Product Moment Correlation analyses demonstrated that there is a moderate correlation between overall sway indexes (OSI) of trials two and three ($r=0.652^{**}$). The Correlation coefficients are presented in Table 2.

Table 2. Pearson Product Moment Correlations between Trials Two and Three of the Overall Sway Index

<table>
<thead>
<tr>
<th>OSI Trial 2</th>
<th>OSI Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI 2 (5.5 ± .9)</td>
<td>1</td>
</tr>
<tr>
<td>SI 3 (5.3 ± 1.0)</td>
<td>0.652^{**}</td>
</tr>
</tbody>
</table>

Note: Values are presented as mean ± SD. OSI Trial 2=Overall Sway Index Trial 2, OSI Trial 3= Overall Sway Index Trial 3.

Table 3 depicts a Pearson Product Moment Correlations between m-CTSIB trials and Stances. There were significant differences between stance 1, m-CTSIB 2, and m-CTSIB 3 ($r=0.697^{**}$) and ($p = 0.000$). Stance 2 of m-CTSIB 2 and m-CTSIB 3 ($r=0.699^{**}$) and ($p = 0.000$), and stance 4, m-CTSIB 2, and m-CTSIB 3 ($r=0.447^{*}$) and ($p = 0.013$) also show significant differences. However, in stance 3 of m-CTSIB 2 and m-CTSIB 3 a correlation of ($r=0.088$) was observed but no significant difference occurred ($p = 0.643$).
Table 3. Pearson Product Moment Correlations between m-CTSIB trials and Stances

<table>
<thead>
<tr>
<th></th>
<th>S1T2</th>
<th>S2T2</th>
<th>S3T2</th>
<th>S4T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(M ± SD)</td>
<td>(.72 ± .29)</td>
<td>(.92 ± .4)</td>
<td>(1.1 ± .28)</td>
<td>(2.7 ± .51)</td>
</tr>
<tr>
<td>S1T3 (.69 ± .31)</td>
<td>.697*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2T3 (.93 ± .4)</td>
<td></td>
<td>.699*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3T3 (1.1 ± .22)</td>
<td></td>
<td></td>
<td>.088</td>
<td></td>
</tr>
<tr>
<td>S4T3 (2.6 ± .53)</td>
<td></td>
<td></td>
<td></td>
<td>.447*</td>
</tr>
</tbody>
</table>

Note: Values are presented as mean ± SD. S1T3 = Stance 1 Trial 3, S2T3 = Stance 2 Trial 3, S3T3 = Stance 3 Trial 3, S4T3 = Stance 4 Trial 3, S1T2 = Stance 1 Trial 2, S2T2 = Stance 2 Trial 2, S3T2 = Stance 3 Trial 2, S4T2 = Stance 4 Trial 2 p < 0.05*
Table 4 demonstrates the OSI for stances 1-4 of trials 2 and 3. With an *a priori* level at *p*<.05. None of the stances demonstrated significant difference between trials two and three.

Table 4. Paired Samples T-Test of the OSI of Trial 2 and Trial 3

<table>
<thead>
<tr>
<th>Groups</th>
<th>Difference Mean ± SD</th>
<th><em>P</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>S1T2- S1T3</td>
<td>.03 ± .24</td>
<td>0.540</td>
</tr>
<tr>
<td>S2T2- S2T3</td>
<td>.01 ± .31</td>
<td>0.851</td>
</tr>
<tr>
<td>S3T2- S3T3</td>
<td>.04 ± .34</td>
<td>0.557</td>
</tr>
<tr>
<td>S4T2-S4T3</td>
<td>.19 ± .54</td>
<td>0.070</td>
</tr>
</tbody>
</table>

Note: S1 A=Stance 1 averages, S2 A=Stance 2 averages, S3 A=Stance 3 averages, S4 A=Stance 4 averages, S1-4 A= Stances 1 through 4 averages

Lastly, table 5 shows the normative values of the sway index scores that BBS utilize for their m-CTSIB stances and the sway index scores from this investigation. The ranges that were recorded for this study do not match up with the normative ranges.

Table 5. Means of the m-CTSIB Stances and Normative BBS Values

<table>
<thead>
<tr>
<th>SI NR</th>
<th>SI CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>.21-.48</td>
<td>.41-1.01</td>
</tr>
<tr>
<td>.48-.99</td>
<td>.54-1.32</td>
</tr>
<tr>
<td>.38-.71</td>
<td>.86-1.36</td>
</tr>
<tr>
<td>1.07-2.22</td>
<td>2.13-3.17</td>
</tr>
</tbody>
</table>

Note: SI NR= Sway Index Normative Range, SI CS=Sway Index Current Study
A paired samples T-test was not performed since there was no difference between the two means of trial 2 and trial 3 between the traditional m-CTSIB protocol scores and the m-CTSIB scores as measured by the BBS (.02 ± .24).

![Figure 1: The sway index averages for stances 1-4](image-url)
CHAPTER V
SUMMARY

The purpose of this study was to determine if BBS was a reliable in measuring balance for the m-CTSIB, and to determine if there was a correlation between the m-CTSIB and the BBS’s m-CTSIB. Limitations of the present study include population size, age, non concussed individuals, neuromuscular adaption, numbers of trials, and physiological reasons, are all possible explanations for the results obtained. The data obtained from trial 1 will not used in the analysis since the BBS had not been calibrated for stability prior to the first trial. Following a protocol for three balance testing sessions and eliminating the data of the first trial led to moderate correlation of m-CTSIB on the BBS between trial 2 and 3.

Cachupe et al. (2001), reported results from a study on the reliability of BBS on dynamic balance using (n=20) participants and was able to obtain moderate to high reliability which is consistent with the results of the present study. However, in the present study it would have been ideal to have a greater population size to test the reliability of the BBS and m-CTSIB protocol.

A moderate correlation was found between the sway indexes of stances 1, 2, and 4 but no correlation in stance 3 was observed. This may be explained since the first 2 stances of the m-CTSIB are performed on a stable surface and the second 2 stances
are performed on a foam pad, the subject must step down off the BBS platform so the foam pad can be placed. The change from a completely static stance to the foam may throw off the balance of the subjects. The loss of the visual and proprioception component of balance cause greater changes of sway and center of mass in the individual are that are detected by the BBS (Aquaroni & Ricci, et al., 2009). Edwards and Patterson (2011) found in their study of gender differences using the m-CTSIB on the BBS that the SI for the third stance showed inferior balance. Cacheupe et al. (2001) also found that the third and fourth stances of the m-CTSIB are normally the most difficult and shows higher sway index scores due to the foam pad and components of balance being altered. These slight differences may not reflective in the m-CTSIB protocol as opposed the BBS because of balance in apparently healthy younger individuals. This may also be attributed to the fact that the m-CTSIB is a fall risk and vestibular assessment protocol for the elderly (Giray et al., 2009). It has been shown that older adults lose balance and neuromuscular control easier than those who are younger (Wrisley & Whitney, 2004). The average age in the present study was twenty-four, in the anticipation of balance becoming better with repeated assessment; trials were completed at least a week apart to prevent this population from gaining an advantage of a learning effect. Aquaroni & Ricci et al. (2009) included participants over the age of sixty five for the m-CTSIB test in their study. Due to the fact that healthy elderly and younger adults use distinct strategies to maintain balance such as stepping or swaying, the differences between balance control in the elderly and younger adults is apparent and must be considered in m-CTSIB testing protocols (Aquaroni & Ricci et al.,
Another point that should be made is the fact that the design study was for apparently healthy individuals. Baselineing with a simple test is not concurrent with a healthy population. The level of difficulty has been shown to improve reliability when testing a healthy population. The difficulty of the m-CTSIB stances proved to be absent during this study since traditional m-CTSIB overall sway indexes were all perfect scores. Although the BESS is the current gold standard in balance assessment for concussions there is not a protocol for BESS on the BBS, but this should be considered for future research when increasing the difficulty for baselining a healthy population.

The Biodex Operation Manual for the BBS includes normative sway index ranges for the m-CTSIB on the BBS (Appendix G). These ranges were decided upon following a study based on (n=100) recruits that were apparently healthy with a mean age of 45. A retest was done 2 weeks later and a third retest on 27 of the original subjects. The normative ranges are listed in Appendix G. Data may be skewed in this current study based on the decreased population size and a younger age group. The m-CTSIB has been studied and evaluated again and again since it was discovered in 1986. Based on current trends and normative ranges of similar objective balance measurement tools the BBS needs further testing to ensure that their normative ranges are standard to the population for m-CTSIB on the BBS (Hunt & Asplund, 2010).

Throughout the course of the study, there were many observations made by the investigators and research participants. Recent research supports that balance and the three components that affect balance, (visual, proprioception, and vestibular) are important factors in a pre and post concussion assessment tool (Guskiewicz, 2001).
the contrary the most current post concussion testing is based on cognitive function of an athlete (Catena & van Donkelarr, 2006). It is important to note that a concussion is a complex injury and the signs and symptoms may be exacerbated by balance testing and possibly delay recovery (McCrory, et al., 2009).

This current investigation is ideally a pilot study for a pre and post concussion protocol for future sports medicine return to play protocols. The m-CTSIB protocol on the BBS must be tested further to obtain more information on age, apparently healthy individuals, and variability between stances to offer a normative sway for physical active adults.

Based on the findings of the present investigation of a moderate correlation, the following recommendations are proposed for future research:

1. Increase population age and size to improve the chance of significant outcomes.
2. Increase the number of trials for each individual
3. Compare pre and post concussion balance testing using the m-CTSIB
4. Compare other balance testing tools such as the BESS on the BBS


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


APPENDICES
APPENDIX A
IRB NOTICE OF APPROVAL
NOTICE OF APPROVAL

February 19, 2013

Jody Duquen
1477 Twinsburg Road
Twinsburg, Ohio 44087

From: Sharon McWhortor, IRB Administrator

Re: IRB Number 201303005 “Measurement of Validity for Balance Assessments using a Modified CTSIB Sway index versus a Biodex Sway index”

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 Expedited Category #4.

Approval Date: February 18, 2013
Expiration Date: February 18, 2014
Continuation Application Due: February 4, 2014

In addition, the following is/are approved:

☐ Waiver of documentation of consent
☐ Waiver or alteration of consent
☐ Research 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 web site at:
http://www.uskrmn.edu/research/onsap/compliance/IRBHome.php

Cc: R. Otterstetter – Advisor
Cc: Valerie Cattman – IRB Chair

☑ Approved consent form/s enclosed
APPENDIX B

INFORMED CONSENT
INFORMED CONSENT FORM

Title of Study: Measurement of validity for balance assessments using a modified CTSIB Sway Index versus a BIODEX Sway Index

Introduction: You are invited to participate in a research project being conducted by Jody Duecker, graduate student enrolled in the Exercise Physiology education program at The University of Akron, under the advisement of Ron Otterstetter, PhD, faculty member at The University of Akron in the Department of Sport Science and Wellness Education.

Purpose: The purpose of the study is to determine the relationship and validity of the Sway Index as measured by the Biodex Balance System (BBS) compared to the Sway Index as measured by the modified-Clinical Test of Sensory Interaction on Balance (m-CTSIB) during a balance assessment protocol. The BBS score is determined by a computer, where the m-CTSIB score is determined subjectively by an individual. Balance is an important consideration when it comes to post-concussion treatments of athletes. To understand deficits or relationships, it is important to understand balance deficits in individuals who have obtained a concussion to determine return to play protocols. It is known that balance is affected following a concussion but clinicians do not rely on objective measurements to clear participants to return to competition. This study would provide an objective tool that can be incorporated in with all the other subjective determinants to return to play decisions.

Procedure: If you volunteer for this study, you will be required to take part in three testing sessions. Each testing session will take approximately twenty minutes, with at least one week between testing sessions. During the first session, the testing protocol will be explained and any questions you have will be answered. Prospective subjects will then complete a health questionnaire. The investigators will then measure and record your age, weight, and height. You will be asked to complete four balance testing conditions with both feet on a balance platform including eyes open, eyes closed, with and without a foam pad. The three test sessions will be conducted the same each time.

Risk and Discomfort: Risks associated with this investigation are minimal falls. It is important to understand that you should inform the researchers immediately if you start to feel dizzy or weak during the testing procedure. A health history will be taken to screen for individuals for neurological disorders, flu or cold symptoms, lower extremity injury, and previous concussion. It is important that you provide truthful and accurate information so you do not put yourself at unnecessary risk.

In the event of a medical emergency, all researchers are CPR, First Aid, and AED trained and certified. If an emergency were to occur, the researchers will activate EMS. An investigator will be monitoring the balance system, and will stop the test at any point that you request or if the researcher feels it is unsafe for you to continue.
**Benefits:** Participating in this study will allow you to learn more about your balance and risk for falling. Your participation will also help us gain information about objective measurements of balance prior to a concussion.

**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:

Jody Duecker  
330-620-4256  
jra18@zips.uakron.edu

Ron Otterstetter  
330-972-7738  
ro5@uakron.edu

Research Advisor

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 C

PARTICIPANT QUESTIONNAIRE
Research Study: Measurement of validity for balance assessments using a modified CTSIB Sway Index versus a BIODEX Sway Index

Subject #___________________________________________ DATE____________________

Please answer the following questions before the initial balance testing.

Are you between the ages of 18-49 ? ____________________________ Yes No

Have you ever been diagnosed with a concussion? ____________________________ Yes No

Have you ever been diagnosed with a neurological/vestibular disorder? ____________________________ Yes No

Do you take medication for a neurological disorder? ____________________________ Yes No

Do you currently have a lower leg injury? ____________________________ Yes No

Please answer the following questions before each week of balance testing.

Have you sustained a lower leg injury since your previous balance testing? ____________________________ Yes No

Have you had a cold or flu like symptoms within the last week? ____________________________ Yes No
APPENDIX D

SCRIPTED RESEARCH STUDY M-CTSIB PROTOCOL ON THE BIODEX BALANCE SYSTEM
To the subject: You are about to complete a balance testing research study. The testing will consist of four separate tests that run for thirty seconds each. Two will be on a flat surface and two will be on a foam surface. I will first explain to you how you are to stand for the testing.

**Condition 1: Double Leg, Firm Surface, Eyes Open**

Please take both of your shoes off and roll your pant legs above the ankle. Please step on the platform.

I will position your feet so that they are centered and balanced, please do not move your feet unless you must catch your balance during the testing or you are told to step off the platform.

Please cross your arms in front of you and put your hands on opposite shoulders. You will need to position your arms this way for each test.

There is a black dot in the center of the screen, try to center the dot on the grid as best as possible and hold the position. The dot will disappear once the test starts.

I will count down the time till the test starts. Each test runs for 30 seconds. Try to keep your balance as best you can. Look straight ahead during this test.

**Condition 2: Double Leg, Firm Surface, Eyes Closed**

For this test your eyes will be closed, I will count down the time till the test starts. Try to keep your balance as best you can. Keep your head up, eyes closed.

Test is finished...please step off the platform
**Condition 3: Double Leg, Foam Surface, Eyes open**

For this test you will be standing on the platform on a foam pad with both feet. Arms crossing, grasping opposite shoulders again. I will position your feet so they are centered and balanced.

Again, center the black dot on the screen.

I will count down the time till the test starts. Each test runs for 30 seconds. Try to keep your balance as best you can. Look straight ahead during this test.

Testing finished….you may step down if you like.

**Condition 4: Double Leg, Foam Surface, Eyes Closed**

For this test you will be standing on the platform on a foam pad with both feet. Arms crossing, grasping opposite shoulders again. I will position your feet so they are centered and balanced.

Again, center the black dot on the screen.

I will count down the time till the test starts. Each test runs for 30 seconds. Try to keep your balance as best you can. Look straight ahead with eyes closed during this test.

Testing finished….you may step down.
APPENDIX E

RETURN TO PLAY PROTOCOL FOLLOWING A CONCUSSION
The Ohio State University Sports Medical Center’s extended return-to-play exertional protocols

Extended 5-Day Return to Play

Day 1
30 to 40 minutes of nonimpact aerobic activity
Exercise bike 15 minutes up to heart rate of 120 bpm
Cool down for 5 minutes
Increase intensity, maximum heart rate of 145 to 150 bpm, maintain for 15 minutes
Cool down for 5 minutes
No additional physical exertion
Immediately discontinue activity if there is any increase in athletes’ symptoms and return to rest without physical activity until symptoms resolve.

Day 2
30 to 40 minutes of nonimpact aerobic activity
Exercise bike 10 minutes up to heart rate of 120 bpm
Cool down for 5 minutes
Increase intensity, maximum heart rate of 145 to 150 bpm, maintain for 25 minutes
Cool down for 5 minutes
No additional physical exertion
Immediately discontinue activity if there is any increase in athletes’ symptoms and return to rest without physical activity until symptoms resolve.

Day 3
45 minutes of aerobic activity including jogging, running, sprints, or position-specific athletic drills; no contact
Cool down for 5 minutes
After at least 30 minute rest may lift weights for 30 minutes
Immediately discontinue activity if there is any increase in athletes’ symptoms and return to rest without physical activity until symptoms resolve.

Day 4
Full participation practice
Immediately discontinue activity if there is any increase in athletes’ symptoms and return to rest without physical activity until symptoms resolve.

Day 5

Full game participation

(Hunt & Asplund, 2010)
APPENDIX F

M-CTSIB CONDITIONS
m-CTSIB Conditions

Condition 1: Eyes open, firm surface (Baseline: incorporates visual, vestibular and somatosensory inputs)
Total time: ___/30 sec
Total time: ___/30 sec
Total time: ___/30 sec Mean score _____

Condition 2: Eyes closed, firm surface (Eliminate visual input to evaluate vestibular and somatosensory inputs)
Total time: ___/30 sec
Total time: ___/30 sec
Total time: ___/30 sec Mean score _____

Condition 3: Eyes open, foam surface (somatosensory interaction with visual input)
Total time: ___/30 sec
Total time: ___/30 sec
Total time: ___/30 sec Mean score _____

Condition 4: Eyes closed, foam surface (somatosensory interaction with vestibular input)
Total time: ___/30 sec
Total time: ___/30 sec
Total time: ___/30 sec Mean Score _____
TOTAL SCORE: ___/120 sec the mean score used for each condition (Hart-Hughes & Haley, 2010).
APPENDIX G

BBS NORMATIVE SWAY INDEX RANGES
BBS Normative Sway Index Ranges

Biodex Balance System

Normative Sway Index ranges are:

Stance 1: Eyes Open firm surface: .21-.48

Stance 2: Eyes closed firm surface: .48-.99

Stance 3: Eyes Open foam surface: .38-.71

Stance 4: Eyes Closed foam surface: 1.07-2.22

(Biodex Medical Systems, Inc.)