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Balance in chronic traumatic brain injury: correlations between clinical measures and a self-report measure

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Abstract

Objective: To assess associations among commonly used self-report and clinical measures of balance in chronic TBI.

Design: Cross-sectional analysis of balance in a convenience sample of individuals at least one year post TBI.

Main Outcome Measures: Activities-Specific Balance Confidence Scale (ABC) (self-reported balance impairment), Community Balance and Mobility Scale (CB&M) (clinical measure validated in TBI), and Balance Evaluation Systems Test (BESTest) (clinical measure not validated in TBI).

Methods: Fifty-nine individuals (64% male, mean age 48.2 years) ambulating independently within the home participated in testing. Pearson correlation coefficients were used to quantify the direction and magnitude of the relationships among the three balance impairment measures.

Results: A significant positive correlation was noted between the ABC and CB&M ($r = 0.42$, $p = 0.0008$), between the ABC and BESTest ($r = 0.46$, $p = 0.0002$), and between the CB&M and BESTest ($r = 0.86$, $p < 0.0001$).

Conclusions: This is the first study we are aware of in the chronic moderate to severe TBI population directly comparing patient's self-reported balance impairment with clinical measures. Positive correlations were found between the self-report measure and both clinical measures. Overall, individuals with chronic TBI tend to self-report less impaired balance than clinical measures indicate. These results provide preliminary evidence to support the need for validation of the BESTest in this population.

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Keywords

Brain injuries; traumatic; balance; outcome assessment; evidence based medicine

Introduction

Traumatic brain injury (TBI) is a common and debilitating injury. In 2013, approximately 2.8 million TBI-related emergency department visits, hospitalizations, and deaths occurred in the United States (1–3). An estimated 5.3 million people in the United States are living with a TBI-related disability (4). Roughly 43% of individuals who acquire a TBI will experience long term impairments (5) including neurocognitive and executive functioning deficits (6), attentional deficits (7), neuromotor impairments (8), dizziness (9), and balance impairments (9,10).

Balance includes the integration and coordination of multiple body systems (11) and is one of the most prevalent long-term impairments that can be addressed by participation in a physical therapy program. Two common methods used by clinicians to provide an objective measure of balance are a functional approach and a systems approach (11).

The functional approach includes an evaluation of the balance impairment in common situations, such as an inability to maintain equilibrium while walking or transitioning from sitting to standing. These tests generally include an evaluation of how long a subject can maintain balance in a particular posture and how well a subject can perform functional tasks. Commonly used functional balance assessments include the Berg Balance Scale, the Functional Gait Assessment (12,13), and the Community Balance and Mobility Scale (CB&M) (14).

The systems approach attempts to identify impaired subcomponents or mechanisms contributing to balance, such as loss of strength or decreased sensation. The main subcomponents examined in this method include biomechanical, motor coordination, and sensory organization. There is frequently overlap of these systems, and often more than one area shows impairment following brain injury (11). The Balance Evaluation Systems Test (BESTest) is an example of a systems based evaluation (15).

Because TBI is such a complex diagnosis, it is difficult to determine how accurately clinical assessments detect specific subsystems of impairment. Multiple systems integrate to assist in maintaining balance, including the visual, sensory, vestibular, and musculoskeletal systems (16,17). Individuals may compensate for mild to moderate deficits by using alternate intact systems, which may provide an inaccurate picture of overall balance (18,19).

After brain injury, the ability to self-report limitations in balance may be impaired (20,21). The correlation of objective balance measures with self-report measures in this population may provide additional valuable information to assist clinicians in designing appropriate rehabilitation strategies for educating patients and families about their specific balance challenges.

The primary objective of this study is to assess the relationship between a self-report measure of balance impairment (ABC) and a functional approach of balance evaluation that has been validated in the TBI population (CB&M). The secondary objectives are to assess the relationship between the ABC and a systems approach to balance evaluation that has not yet been validated in the TBI population (BESTest), and to assess the relationship between functional (CB&M) and systems based (BESTest) approaches to clinical evaluation of balance.

Methods

Design overview

This is a cross-sectional analysis of a group of community-dwelling individuals at least one year post TBI initially requiring inpatient hospitalization, who are experiencing ongoing balance impairments (CB&M ≤ 75). This was a convenience sample of individuals enrolled in a larger randomized controlled trial evaluating the use of virtual reality in the home setting to address balance impairment. The inclusion and exclusion criteria for the larger study are summarized in Table 1. All procedures were approved by and followed protocol and ethical standards of the local Institutional Review Board. Participants completed the CB&M, a virtual reality screen, a vision screen, and the BESTest, in that order. The average time to complete this testing was 98 minutes (range: 75 to 140 minutes). Participants then completed a neuropsychological battery and the ABC with a research assistant. Physical testing was conducted by physical therapists (PTs) with an average of eight years of clinical experience. All PTs underwent training and scored two videos of individuals with balance impairments performing the BESTest and CB&M prior to testing participants. All discrepancies were discussed as a group. Throughout the study, testers met every 6–9 months to review scoring reliability.

Setting and participants

Testing occurred in a rehabilitation hospital with standardized equipment and location. Participants were recruited through mailings, posters in the hospital, contact with area rehabilitation sites, and word of mouth.

The sample consisted of 59 subjects, 64% male and 95% white, with a mean age of 48 years and median number of years since injury of 4.8. See Table 2 for additional characteristics.

Outcomes

Activities-Specific Balance Confidence Scale (ABC)—The ABC is a self-report measure of fear of falling during community activities such as reaching for a can, walking through a crowded mall, and walking on an icy sidewalk. This 16-item measure is scored from 0 (no confidence) to 100 (complete confidence). Lower scores represent greater fear of falling (22). This scale has excellent test-reset reliability, excellent internal consistency, and adequate content validity (23). The ABC has been used in previous TBI research, and although not specifically designed for this population, it has been shown to be sensitive to treatment effects (24–26).

Community Balance and Mobility Scale (CB&M)—This standardized clinical assessment of balance impairments includes 13 functional balance activities, including walking with head turns holding a weighted object, walking while picking a beanbag up off of the ground, hopping, and stair descent. The CB&M is scored from 0–96 points, with higher scores indicative of less impairment (14).This outcome was specifically developed for individuals with TBI. The CB&M has excellent inter-rater, intra-rater, and test-retest reliability for the TBI population (14). Prior studies using the CB&M for people with TBI have had means and standard deviations ranging from 51.1 to 57.8 and 18.3 to 23.3, respectively (14,26).

Balance Evaluation Systems Test (BESTest)—The BESTest is a standardized 36-item clinical test of balance impairments scored using a scale of 0 (maximum limitation) to 3 (within normal limits). This test is scored out of 108 points, then converted to a scale of 0–100 and reported as a percentage. The test is divided into 6 subscales, corresponding with Horak's six balance systems (15): Biomechanical Constraints, Stability Limits/Verticality, Anticipatory Postural Adjustments, Reactive Postural Responses, Sensory Orientation, and Stability in Gait (15). This measure has high inter-rater reliability, high test-retest reliability, and good validity in fall prediction for individuals with Parkinson's Disease (27,28). This measure has frequently been used in the Parkinson's disease and vestibular disorder population, but has not been commonly used in TBI (29).

Data analysis

SAS v.9.4 (30) was used for all data analysis assuming a significance level of 0.05 unless otherwise specified. Subject characteristics were described using frequency counts/percentages for categorical variables and mean/standard deviation (SD) or median/interquartile range (IQR) for continuous variables. Pearson correlation coefficients were used to quantify the direction and magnitude of the relationships among the three balance impairment measures. Fisher's z-transformation was used to compute 95% confidence intervals and for significance testing.

Results

The ABC total scores ranged from 40.0 to 99.4, with a mean of 79.4 (SD = 13.6). The CB&M total scores ranged from 0 to 75, with a mean of 46.2 (SD = 18.3). The (rescaled) BESTest total scores ranged from 15.7 to 96.3, with a mean of 73.8 (SD = 16.0) (Figure 1).

The associations among the three balance impairment measures are shown with scatterplots in Figure 2a–c. There was a significant positive correlation of 0.42 between ABC and CB&M total scores (95% CI = 0.19, 0.61, $p = 0.0008$). There was a significant positive correlation of r = 0.46 between ABC and (rescaled) BESTest total scores (95% CI = 0.24, 0.64, $p = 0.0002$). There was a significant positive correlation of 0.86 between CB&M and (rescaled) BESTest total scores (95% CI = 0.78, 0.92, $p < 0.0001$).

The association between CB&M total scores and BEST subscales scores was also examined within the each of the 6 BESTest subscales (see Figure 3). There were significant positive correlations between CB&M total scores and each BEST subscale score (all p-values

< 0.0001): Biomechanical Constraints (r = 0.69, 95% CI = 0.52, 0.80), Stability Limits/ Verticality (r = 0.67, 95% CI = 0.50, 0.79), Anticipatory Postural Adjustments (r = 0.78, 95% CI = 0.66, 0.87), Reactive Postural Responses (r = 0.67, 95% CI = .50, 0.79), Sensory Orientation (r = 0.54, 95% CI = 0.33, 0.70), and Stability in Gait (r = 0.84, 95% CI = 0.74, 0.90).

Discussion

Measurable balance impairment and self-perception of impairment are key clinical factors addressed in rehabilitation after TBI. In a group of community-dwelling individuals with chronic TBI, we found significant positive correlations between a self-reported balance measure (ABC) and two commonly used balance outcomes (CB&M, BESTest).

The ABC and CB&M were positively associated (see Figure 2a). CB&M total scores were consistently below the identity line in this figure. Additionally, ABC scores less than 40 were not observed in this sample, while the full range of CB&M scores for our sample (0–75) was observed. Although these measures are not directly correlated with each other, this does suggest a trend of self-report of less balance impairment despite clinical scores that indicate higher balance impairment.

The comparison of BESTest and ABC scores was relatively similar and showed a positive association, but was suggestive of an interesting trend (see Figure 2b). As individuals had higher scores on the BESTest, suggesting less balance impairment, there was a trend towards lower ABC scores, indicating self-report of more impairment.

It is not clear why this separation was seen with BESTest scores and not CB&M scores. Following a TBI, it is often assumed that an individual has decreased awareness of his or her impairments which may lead to overestimating of balance abilities (24). Our results were consistent with this assumption when evaluating the association of the CB&M and the ABC, but showed variability when evaluating the association of the BESTest and the ABC. It is possible the BESTest is more sensitive to these changes in insight, and may therefore be a more appropriate measure to guide methods of education for balance safety. Another possible explanation is that participants with higher CB&M scores (>75) were not included in this sample which may provide incomplete information about how individuals who score higher on the CB&M perceive their balance impairment. Further investigation is warranted to clarify how the BESTest correlates to self-reported balance measures that have been validated in TBI (21), as these finding suggest the BESTest may be more sensitive than the CB&M in discerning between individuals who may be at a higher fall risk due to lack of insight and those who may be self-limiting due to fear or hyperawareness of balance deficits.

This discrepancy of balance perception between those who are most and least impaired may have important clinical utility as therapists are teaching individuals with TBI how to compensate for their deficits when returning back into their communities. The approach to teaching balance strategies and educating on safety differs depending on whether an individual overestimates or underestimates their balance impairment. If someone tends to overestimate impairment, the clinical emphasis may be on pushing the individual to use their

appropriate balance systems and to fully engage in their home and community environments without limiting activity due to fear of falling. However, if someone underestimates their impairment, the clinical emphasis will focus on increasing insight into deficits, up-training systems that are not as efficient to prevent losses of balance, and educating the individual and their family/caregivers on strategies and environmental management techniques to improve home and community safety.

The BESTest and CB&M (see Figure 2c) showed a consistent association as noted by the regression line. Individuals with higher total scores on the BESTest tended to have higher scores on the CB&M. Both tests evaluate dynamic balance and incorporate functional tasks, although the CB&M uses primarily a functional approach and the BEST uses primarily a systems approach. The BESTest has not yet been validated or well tested in TBI. However, in other neurological populations the BESTest has been found to have excellent test-retest and inter-rater reliability (27,31). The few studies that have used this tool in TBI have not provided a comparison to other validated measures (29,32,33). Leddy *et al* (27). found an excellent correlation between the BESTest and the ABC in individuals with Parkinson's Disease while Chinsongkram *et al* (31). found an excellent correlation between the BESTest and the CB&M for individuals with subacute stroke. Additional research and tool validation would be beneficial to further define the benefits of the BESTest for evaluating balance impairment in individuals following TBI.

Interestingly, the two clinical balance measures (CB&M and BESTest) correlated highly with each other ($r = 0.86$), more so than either measure correlated with the ABC ($r = 0.42$ and 0.46, respectively). This may indicate more reliable and consistent information when using clinical measures compared to self-reported measures in the chronic TBI population.

There was not a statistically significant relationship between the lowest subscale score on the BESTest and the total score on the CB&M (see Figure 3). In general, individuals with lower scores on the Sensory Orientation subscale had lower CB&M scores, possibly because the sensory orientation subscale evaluates the complex integration of the visual, vestibular, and proprioceptive systems and may indicate an overall larger balance deficit. The individuals with lower scores on the stability limits subscale tended to have higher scores on the CB&M. This subscale includes items such as a forward and lateral reach which generally indicate advanced balance recovery and increased use of anticipatory postural adjustments (34).

Study limitations

This was a convenience sample of individuals who met criteria for a larger study. There is limited generalizability of these findings to the TBI population as a whole because this cohort represents individuals who are ambulating without assistance but with ongoing balance deficits. Individuals with CB&M scores of less than 75 were screened out of the study and did not participate in further testing. This cohort included predominately white males with some level of college education. In the US, the population of individuals living with a TBI from 2001–2007 was 65.2% male and 77.5% Caucasian (35), and in general, education is positively correlated with cognitive status following a TBI (36). Participants underwent a long battery of tests in one session; fatigue from the extensive testing may have

impacted outcomes. A larger sample size may provide more robust results when evaluating these measures in future studies.

Conclusions

This study adds to the limited literature on balance outcome measures used in TBI rehabilitation. The ABC, CB&M, and BESTest are all positively correlated. In general, individuals with TBI tend to underestimate their balance deficits in comparison to their score on the CB&M. Individuals with higher scores on the BESTest tend to overestimate their balance impairment, while those with lower scores tend to underestimate their balance impairment. This research also demonstrates a positive relationship between the BESTest and the CB&M, a measure already validated in TBI. Overall, patient self-report of balance deficit correlates with objective scores even though patients tend to underestimate their balance impairment. Though further study and validation is warranted, the BESTest may be a beneficial assessment in the chronic TBI population.

Disclosure Statement

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Abbreviations:

ABC	Activities-specific balance confidence scale
BESTest	balance evaluation systems test
BOS	base of support
COM	center of mass
CB&M	community balance and mobility scale
CI	confidence interval
IQR	interquartile range
PTs	physical therapists
SD	standard deviation
SE	standard error
TBI	traumatic brain injury

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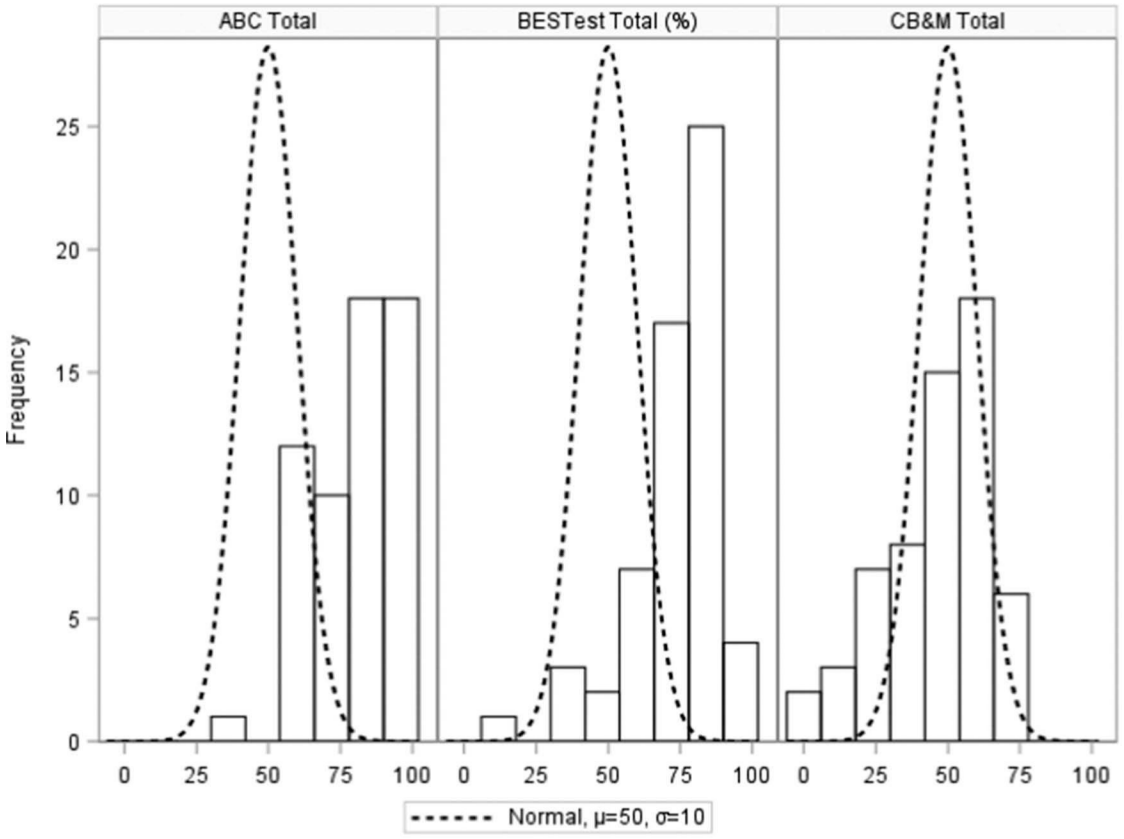

Figure 1.
Distributions of CB&M, BESTest (%), and ABC Total scores.

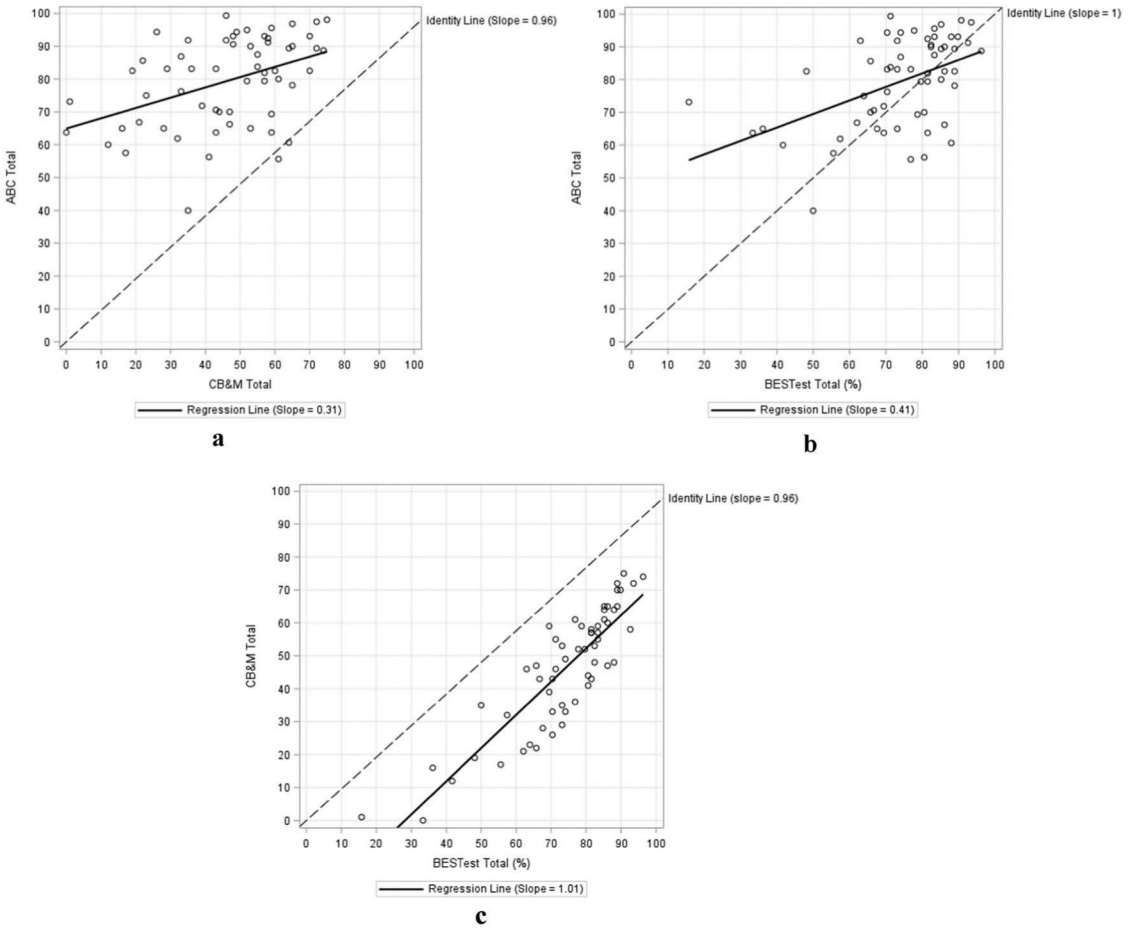

Figure 2.

Associations of CB&M total scores with BESTest and ABC total scores. (a) Association between ABC and CB&M total scores ($r = 0.42$) (b) Association between ABC and BESTest (%) Total scores ($r = 0.46$) (c) Association between CB&M and BESTest (%) total scores ($r = 0.86$).

Dashed identity lines depict one-to-one relationship between X and Y variables.Solid regression lines depict estimated relationship between X and Y variables.

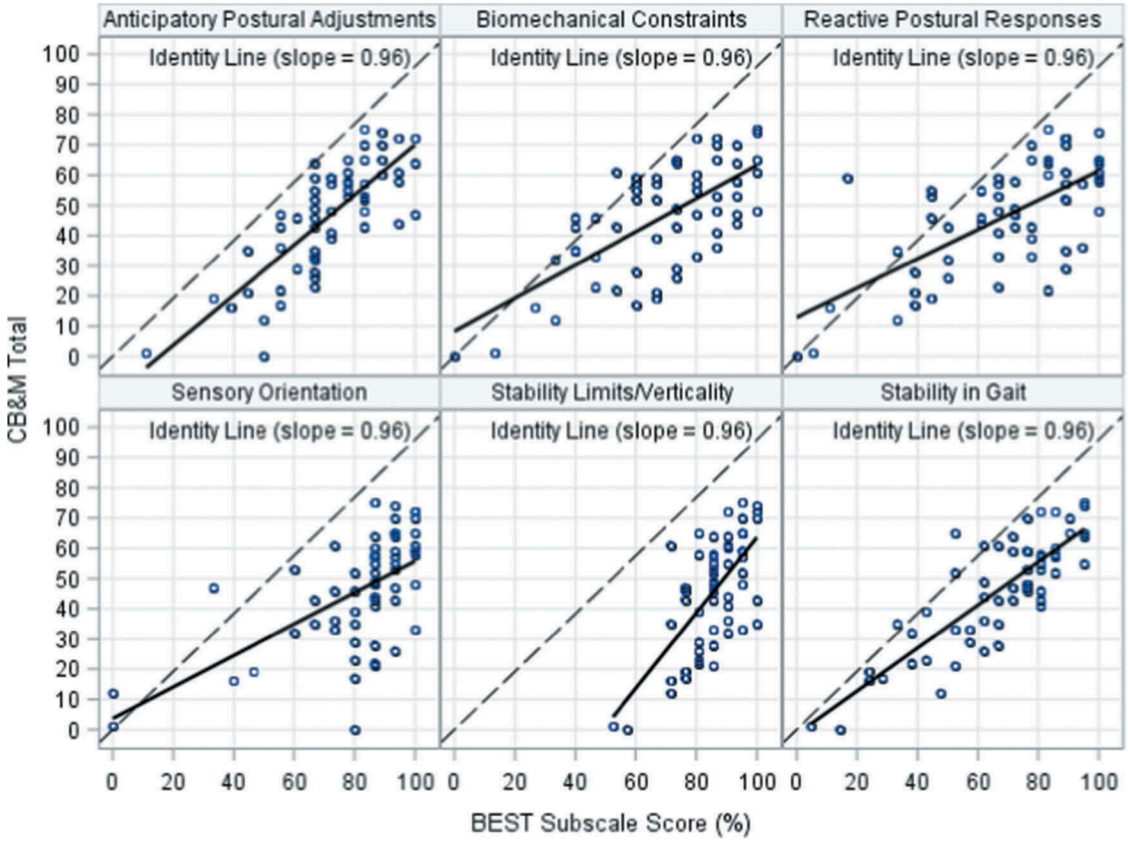

Figure 3.

Association between CB&M total scores and best subscale scores.

Dashed identity lines depict one-to-one relationship between X and Y variables.Solid regression lines depict estimated relationship between X and Y variables.

Table 1.

Inclusion and exclusion criteria for the larger RCT.

Inclusion Criteria	Exclusion Criteria
• Sustained a documented TBI that required an inpatient rehabilitation program • At least 1 year post TBI • At least 18 and no more than 64 years of age at the time of enrollment • English or Spanish speaking • At least 3 months beyond completion of formal PT, including acute inpatient rehabilitation, outpatient and home-based therapy • Provides written medical clearance for participation in an in-home balance exercise program • Ambulates independently within the home (with assistive devices and/or orthotics as needed) • Active range of motion of bilateral upper extremities of at least 90 degrees of abduction to allow for control of the VR system • Completes a 15 minute trial using a VR system in the absence of a negative physical or behavioral reaction • Self-reports ongoing balance deficits and demonstrates such deficits by scoring at or below one standard deviation above the mean (75 or below) on the CB&M • Provides informed consent, or has a guardian available to provide consent	• History of another medical illness or neurological disorder which may affect balance • Experienced a seizure within the last year • Psychiatric disorder requiring hospitalization • Currently participating in another RCT • Currently using VR technology to address specific balance goals • Unable to travel to Craig for assessments throughout the study period • Unable to communicate effectively to complete standardized assessments • Cognitive impairment that precludes completion of baseline testing • Unavailable to participate in 12 continuous weeks of therapy • No access to television able to connect to VR gaming system • Reports inadequate space required for VR gaming system sensors

Table 2.

Sample characteristics ($N = 59$).

	***N* (%)**
Gender	
Male	38 (64)
Female	21 (36)
Race/Ethnicity	
White	56 (95)
Black	1 (2)
Hispanic Origin	2 (3)
Cause of injury	
Motor vehicle	27 (46)
Bicycle	8 (14)
Fall	10 (17)
Other	14 (24)
Years of education	
High school diploma	9 (15)
Some college	25 (42)
Bachelor's degree	12 (20)
Post-bachelor's degree	13 (22)
Employment status	
Competitively employed	17 (29)
Retired	20 (34)
Unemployed/other	22 (37)
Marital status	
Single	14 (24)
Married	34 (58)
Divorced	10 (17)
Widowed	1 (2)
Living arrangement	
Live alone	13 (22)
Live with spouse	34 (58)
Live with parent(s)	8 (14)
Other	4 (7)
Age, mean (SD)	48.2 (12.3)
Years since injury, median (IQR)	4.8 (2.6, 11.0)

SD = standard deviation; IQR = interquartile range.