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ORIGINAL RESEARCH

# Using sideline concussion tests in the emergency department



This article was published in the following Dove Press journal:
Open Access Emergency Medicine

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**Purpose:** Traumatic brain injury (TBI) is a significant cause of death and disability in the United States. Many patients with TBI are initially treated in the emergency department (ED), but there is no evidence-based method of detecting or grading TBI in patients who have normal structural neuroimaging. This study aims to evaluate the validity of two common sideline concussion tests. The Concussion Symptom Severity Score (CSSS) and modified Balance Error Scoring System (mBESS) tests are well-validated sideline tests for concussion, but have not been validated in the setting of non-sport-related concussion, in settings other than the sideline or athletic training room or in moderate or severe TBI.

**Patients and methods:** One hundred forty-eight subjects who had sustained a TBI within the previous 72 hours and 53 healthy control subjects were enrolled. CSSS and mBESS were administered. Clinical outcomes were followed up prospectively.

**Results:** The CSSS was collected in 147 TBI subjects but only 51 TBI subjects were able to complete the mBESS. The CSSS was collected for all 53 control subjects, and the mBESS was completed for 51 control subjects. The mean CSSS for TBI and control subjects was 32.25 and 2.70, respectively ($P < 0.001$). The average mBESS for TBI and control subjects was 7.43 and 7.20, respectively ($P = 0.82$). CSSS greater than 5.17 was 93.43% sensitive and 69.84% specific for TBI.

**Conclusion:** The mBESS is poorly tolerated and, among those who can complete the test, not sensitive to TBI in the ED. The CSSS is both sensitive to TBI and well tolerated.

**Keywords:** traumatic brain injury, balance, emergency room, Sport Concussion Assessment Tool, concussion symptom severity score, modified balance error scoring system

## Introduction

A traumatic brain injury (TBI) is any injury that disrupts the normal function of the brain. The Centers for Disease Control and Prevention (CDC) estimated that in 2010, TBI accounted for approximately 2.5 million emergency department (ED) visits, hospitalizations, and deaths in the United States.[1] Leading causes of TBI are falls, being struck by an object/person, motor vehicle accidents, and assaults.[2] TBI is a preventable public health issue and is currently the leading cause of injury-related death and disability in the United States.[2] Economically, ED visits, hospitalizations, and deaths have an annual economic burden of $82 billion.[2]

The CDC, National Institutes of Health (NIH), Department of Defense (DOD), and even Congress continue to prioritize TBI research.[3–5] Most of our understanding of TBI centers around athletes and, more recently, military personnel with combat injuries.[6] The majority of these TBIs are concussion, a subset of mild TBI. The

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http://dx.doi.org/10.2147/OAEM.S165995

Sport Concussion Assessment Tool version 3 (SCAT3) is commonly used for the identification and monitoring of sport-related concussion.[7] The SCAT3 is the third revision of a tool for physicians and health care providers for assessing for concussion during the care of injured athletes.[7] The Concussion Symptom Severity score (CSSS) and modified Balance Error Scoring System (mBESS) are two important components of the SCAT3.

The CSSS is a concussion symptom checklist that uses a 22-item questionnaire and a 7-point Likert rating scale to assess for the presence and severity of each concussion symptom. Concussion symptom checklists are the most common post-concussion evaluation tool for sport-related concussion.[8] The CSSS is one of the most studied of the available checklists and symptom scales. The CSSS has been demonstrated to be a reliable and valid assessment for sport-related concussion symptoms.[7,9–17] The CSSS has also been used to monitor recovery after injury[7,9,18] and in non-sport-related TBI patients with injuries severe enough to require computed tomography (CT) imaging.[19]

The mBESS evaluates the postural stability and balance without needing any complex or expensive equipment.[20] Of the available and recommended balance examinations, the mBESS is the balance test found to be more effective at identifying patients with concussion.[21,22] While the mBESS has been shown to have moderate to high reliability, it has low to moderate validity and must be administered before the athlete returns to normal balance measurements (3–5 days after the injury).[21–24] The mBESS has been studied and validated in the setting of sport-related concussion[21–24] and has well-established normalized baseline data.[25–27] But the mBESS has not been well studied in other settings.

The CSSS and mBESS tests are well-validated sideline tests for concussion, but they are also commonly used in other settings. Anecdotally, the SCAT3 is among the most common concussion evaluation tools used in athletic training rooms, clinics, and EDs, although they are not designed for use in these settings. Neither test has been validated in the setting of concussion in a non-sport-related setting, such as in an ED, or during moderate or severe TBI.[28] This study aims to evaluate this common, but unproven, practice. The aims of the study were to 1) determine what proportion of non-sport-related TBI patients and control subjects can complete the CSSS and mBESS and 2) among those who can complete the testing, determine if ED TBI patients (a non-sport-related setting) are statistically different from subjects who have not sustained a TBI. The CSSS and mBESS are relatively quick and easy to administer. If validated in ED, the CSSS and mBESS could be used in non-sport-related settings for diagnosis and monitoring of TBI.

# Patients and methods

## Study design and setting

This is a case–control study of the effectiveness of the CSSS and mBESS to identify ED patients with TBI. All subjects were recruited from a university hospital ED and level one trauma center, seeing approximately 60,000 patient visits each year from April 2015 to February 2017. Approval was obtained from the institutional review board at the University of Iowa. All subjects provided written informed consent before participating in the study.

## Selection of participants

TBI subjects were adults who have sustained a suspected brain injury within the previous 72 hours. TBI severity was classified based on the Glasgow Comma Scale (GCS). Control subjects were adults without a history of head trauma and had a Glasgow coma score of 15. Control subjects were recruited through the institution's Clinical Research Unit and were either family members of patients within the ED or were ED patients who were seeking care for something other than a head injury. All subjects were aged between 18 and 65 years.

Exclusion criteria for both groups included current neurological disease, current psychological disorder, history of substance or alcohol abuse, current intoxication, documented current diagnosis or treatment of cancer (including sickle cell disease), current treatment to the head/brain (radiation, whole brain therapy, and gamma knife), head injury in the last 2 years, unwilling or unable to sign informed consent, and pregnant or potentially pregnant.

## Methods and measurements

The TBI subjects were identified by ED staff and then approached by the research personnel. The ED staff determined the GCS as a part of routine clinical care. GCS of the control subjects was assessed by the research personnel. Control subjects had to have a Glasgow coma score of 15 and no history of TBI. Three assessments were administered in the privacy of an ED room: screening and demographics form, CSSS, and mBESS. The CSSS questionnaire was administered and scored by the study personnel. All subjects were instructed to perform the mBESS (although, as described below, most subjects were unable or unwilling to do so). All three parts were conducted in doorway or near a wall so that if subjects became unstable they could reach out and touch it. The study coordinator was also present as a spotter. The

treating providers were blinded to the results of the mBESS and CSSS, and the results were not used for treatment or disposition decisions.

The CSSS is a questionnaire from SCAT3.[7] Subjects are instructed, "You should score yourself based on the following symptoms, based on how you feel now". The 22 different symptoms are as follows[7]:

1. Headache
2. "Pressure in head"
3. Neck pain
4. Nausea or vomiting
5. Dizziness
6. Blurred vision
7. Balance problems
8. Sensitivity of light
9. Sensitivity to noise
10. Feeling slowed down
11. Feeling like "in a fog"
12. "Do not feel right"
13. Difficulty concentrating
14. Difficulty remembering
15. Fatigue or low energy
16. Confusion
17. Drowsiness
18. Trouble falling asleep
19. More emotional
20. Irritability
21. Sadness
22. Nervous or anxious

Each symptom is rated as none (0), mild (1 or 2), moderate, (3 or 4), and severe (5 or 6). The score for each symptom is totaled for a maximum score of 22 times 6 or 132.

The mBESS is the balance examination from SCAT3.[7] It is conducted in three parts. Part one is the double-leg stance. The subjects stand with both feet together, arms by their side, and eyes closed for 20 seconds. Any time that the subject becomes unbalanced, steps off to the side, puts an arm out, or opens their eyes during the 20-second time period is considered as an error. The total number of errors in the 20-second period is recorded. Part two is the single-leg stance. This is conducted similar to the double-leg stance except the subjects are balancing on their nondominant foot instead of both feet. Part three, tandem stance, is similar to the other two except the subjects are standing with their nondominant foot directly behind their dominant foot. The feet should be in a straight line with the toes of the nondominant foot touching the heel of the dominant foot. The mBESS is calculated by adding one point for each error during the three tests. There is a maximum of 10 for each test and therefore a total maximum score of 30. If a subject is unable to maintain the test for 5 seconds, then they are given the maximum points, 10. The mBESS is completed on a hard surface such as hospital floor.[7] Research personnel were all taught how to complete the mBESS by the principal investigator (AJK).

Intrarater and interrater variability have been completed on the total Balance Error Scoring System (BESS). The total BESS consists of the mBESS, but also the same protocol completed on a foam surface.[27] The total BESS has intrarater reliability ranging from intraclass correlations (ICCs) of 0.60–0.92. Interrater reliability ranges from 0.57 to 0.85.[24]

The GCS is composed of three parts: eye response, verbal response, and motor response. Eye response is graded from 1 to 4. Verbal response is graded from 1 to 5. Motor response is graded from 1 to 6. The GCS is the sum of all three parts for a maximum score of 15. A TBI was classified as minor (GCS of 15–13), moderate (GCS of 12–9), or severe (GCS of 8–13) based on the GCS.[29,30]

## Outcomes

Primary outcomes were the ability to complete each test, CSSS, and total mBESS. Secondary outcomes were analyzed for the TBI subjects and included severity of the TBI (based on the GCS), brain imaging status (none, normal, or abnormal), admission status, length of stay, history of head injury, and history of frequent headaches. Severity of the TBI was evaluated to determine if either test could predict the severity of a TBI. Imaging, admission, and length of stay were evaluated to determine if the test could predict hospital outcomes. History of head injuries and headaches were evaluated to determine if either of these historical factors might influence the test scores.

## Analysis

An a priori power analysis was performed to determine the sample size. The power calculations from the pilot data showed that the mBESS needed more subjects than the CSSS for the study to be fully powered. Assuming normal distribution, 80% power, an alpha of 0.05, and an mBESS mean difference of 1.78 with an SD of 3.14 (from the pilot study), the study needed an analysis sample of 102 subjects (51 TBI cases and 51 control subjects). The pilot data suggested that only 33% of TBI subjects were able to complete the mBESS. Therefore, a 3:1 ratio of TBI subjects to control subjects was desired (153 TBI cases and 51 control subjects).

All analysis was completed using MATLAB, version 9.0 (MathWorks, Natick, MA, USA). Normality was determined by plotting histograms of the data as well as evaluating the data using the Anderson–Darling test. The Kruskal–Wallis test was used for comparing continuous non-normal distributions, and the Pearson chi-square test was used to compare all categorical variables by TBI status. Sensitivity and specificity were calculated for various CSSS levels and evaluated for optimal performance. Box plots were used to present the mean, median, and interquartile ranges (IQRs).

# Results

## Subjects

A total of 148 subjects with TBI and 53 control subjects were enrolled. Descriptive statistics for age, sex, ethnicity, and race are summarized in Table 1. The age distributions of neither TBI subjects nor control subjects were normally distributed. The median age for control subjects was 40 (IQR = 25–51.25) years, whereas the median age for TBI subjects was 41.5 (IQR = 24–55) years ($P = 0.52$). Control subjects were 69.81% female and TBI subjects were 53.37% female ($P = 0.038$). Ethnicity and race were not statistically significant between TBI and control groups.

Detailed CSSS and mBESS results are shown in Table 2. Of the total 148 TBI subjects, the CSSS was collected for 147 subjects. The subject missing the CSSS was given the form to fill out, but the form was not collected before the subject was discharged from the ED. The CSSS was collected for all 53 control subjects.

Of the total 148 TBI subjects, only 51 subjects were able to complete the mBESS. Reasons for not completing the mBESS are detailed in Table 3. The most common reason for not completing the mBESS was that the subject was in a C-collar (33.0%). This was followed by the subject declining to perform the mBESS or stating that they did not feel up for completing the mBESS (23.71%). The mBESS was conducted in 51 of 53 control subjects. One subject was not able to do the mBESS due to balance issues resulting from lower extremity surgery

**Table 1** TBI subject demographics

| Characteristics | TBI subjects (N = 148) | Control subjects (N = 53) | *P*-value |
|---|---|---|---|
| Age (years), median (IQR) | 41.5 (24–55) | 40 (25–51.25) | 0.52 |
| Sex, female (%) | 79 (53.37) | 37 (69.81) | 0.038 |
| **Ethnicity (%)** | | | 0.44 |
| Not Hispanic or Latino | 133 (89.86) | 49 (92.45) | |
| Hispanic or Latino | 9 (6.08) | 1 (1.89) | |
| Subject chose not to provide information | 6 (4.05) | 3 (5.66) | |
| **Race (%)** | | | 0.12 |
| White | 127 (85.81) | 42 (79.25) | |
| Black or African American | 7 (4.73) | 6 (11.32) | |
| Asian | 0 (0) | 2 (3.77) | |
| Others | 8 (5.41) | 1 (1.89) | |
| Subject chose not to provide information | 6 (4.05) | 2 (3.77) | |

**Note:** Ability to complete CSSS and mBESS.
**Abbreviations:** CSSS, Concussion Symptom Severity Score; mBESS, modified Balance Error Scoring System; TBI, traumatic brain injury.

**Table 2** Results of CSSS and mBESS for TBI and control subjects

| Characteristics | TBI subjects (N = 148) | Control subjects (N = 53) | *P*-value |
|---|---|---|---|
| **CSSS** | | | |
| Subjects able to complete | 147 | 53 | |
| Mean ± SD | 32.25 (24.01) | 2.70 (6.88) | |
| Median (IQR) | 29 (15.25–43) | 0 (0–1.25) | <0.001 |
| **mBESS** | | | |
| Subjects able to complete | 51 | 51 | |
| Mean ± SD | 7.43 (4.99) | 7.20 (3.64) | |
| Median (IQR) | 7 (4–10) | 7 (4.25–10) | 0.82 |

**Abbreviations:** CSSS, Concussion Symptom Severity Score; IQR, interquartile range; mBESS, modified Balance Error Scoring System; TBI, traumatic brain injury.

**Table 3** Reasons for not completing mBESS

| Reasons | TBI subjects not able to complete mBESS (N = 97) |
|---|---|
| Subject was in a C-collar (%) | 32 (33.0) |
| Subject declined or did not feel up for it (%) | 23 (23.7) |
| Subject had other injuries that limited them (%) | 16 (16.5) |
| Subject was in too much pain to participate (including headache and neck pain) (%) | 11 (11.3) |
| Subject was deemed a fall risk or physician did not want them out of bed (%) | 9 (9.3) |
| Subject states that they were too dizzy (%) | 6 (6.2) |

**Abbreviations:** mBESS, modified Balance Error Scoring System; TBI, traumatic brain injury.

and had to wear a leg brace. Another control subject was not able to perform the mBESS due to the leg length discrepancy.

In comparing the TBI subjects who were able to complete the mBESS and those not able to perform the mBESS, the demographic information was not statistically different: age ($P = 0.52$), sex ($P = 0.54$), ethnicity ($P = 0.11$), and race ($P = 0.85$). There was no statistical difference in CSSS of TBI subjects able to and not able to complete the mBESS ($P = 0.13$).

## Comparison to control subjects

The average CSSS for TBI subjects was 32.25, and the average CSSS for control subjects was 2.70, depicted in Table 3 and Figure 1.

The average mBESS of TBI subjects who were able to complete the mBESS was 7.43, and the average mBESS of control subjects who were able to complete the mBESS was 7.20, depicted in Table 3 and Figure 2.

The a priori analysis assumed normal distribution. On analyzing the data, only the total mBESS of control subjects was normally distributed. The CSSS for TBI and control subjects as well as the mBESS for TBI subjects were not normally distributed. Post hoc analysis was then completed using median and IQRs. Likewise, *P*-values correspond to the difference in medians.

The median CSSS for TBI subjects was 29 (IQR, 15.25–43), and the median CSSS for control subjects was 0 (IQR, 0–1.25; $P < 0.001$). A CSSS cutoff of 5 resulted in the best balance of sensitivity and specificity. The CSSS >5 was 93.43% sensitive and 69.84% specific for TBI.

Among subjects who completed the mBESS, the median mBESS for TBI subjects was 7 (IQR, 4–10), and the median mBESS for control subjects was 7 (IQR, 4.25–10; $P = 0.82$).

## Secondary post hoc analysis

The a priori research questions revolve around the first two aims, but a subsequent post hoc analysis was performed to determine if either CSSS or mBESS was useful in discriminating TBI severity and outcomes. Of the 148 TBI subjects,

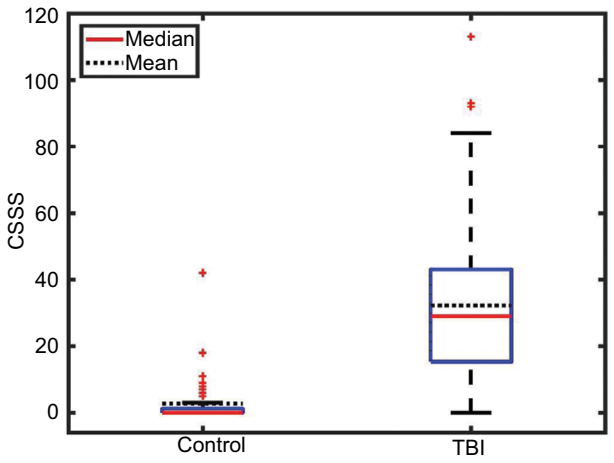


**Figure 1** CSSS for control and TBI subjects.
**Note:** The red line indicates the median value; the dashed black line indicates the mean value; the top and bottom of the blue box are the 25th and 75th percentiles, respectively; the red asterisks were considered outliers (more than 1.5 times the interquartile range).
**Abbreviations:** CSSS, Concussion Symptom Severity Score; TBI, traumatic brain injury.

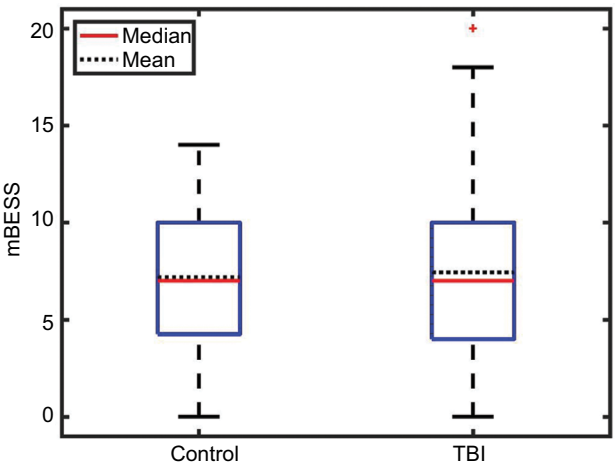


**Figure 2** mBESS for control and TBI subjects.
**Note:** The red line indicates the median value; the dashed black line indicates the mean value; the top and bottom of the blue box are the 25th and 75th percentiles, respectively; the red asterisks were considered outliers (more than 1.5 times the interquartile range).
**Abbreviations:** mBESS, modified Balance Error Scoring System; TBI, traumatic brain injury

147 were rated as minor, 1 was rated as moderate, and 0 were severe. There were 47 TBI subjects who did not have any imaging, 83 had normal imaging, and 18 had abnormal brain imaging. Brain imaging was either brain CT or brain magnetic resonance imaging (MRI). Normal imaging has the highest median CSSS (32), but this was not significantly different from no imaging or abnormal brain imaging ($P$ = 0.10). Imaging statistics are presented in Table 4 and Figure 3.

Of the TBI subjects, 35 were admitted to the hospital. The median CSSS for admitted TBI subjects was 25, and the median CSSS for non-admitted subjects was 30 ($P$ = 0.36; Table 4 and Figure 4). The CSSS was not statistically different based on the number of days stayed in the hospital ($P$ = 0.57; Table 4 and Figure 5).

The CSSS for TBI subjects with a history of head injury or frequent headaches is presented in Table 5. TBI subjects with (n = 40) and without (n = 108) a prior head injury had a median difference in the CSSS of 6, but were not statistically different ($P$ = 0.090). TBI subjects with frequent headaches (n = 37) had a statistically significant median difference of 8 ($P$ = 0.010), also presented in Figure 6.

## Discussion

Demographically the TBI and control subjects were similar except for the difference in sex. The difference in sex resulted from difficulty initially recruiting male control subjects. Further analysis showed that there was no statistical difference in the CSSS ($P$ = 0.43) and mBESS ($P$ = 0.27) scores of the female and male control subjects.

Our first aim was to determine how well the CSSS and mBESS were tolerated by brain injury patients and controls

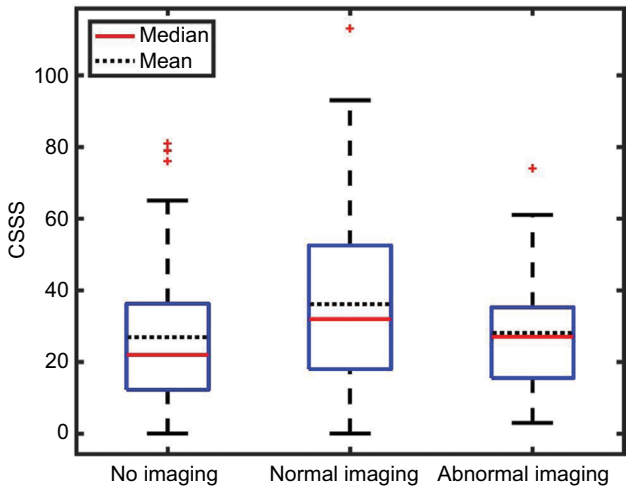


**Figure 3** CSSS of TBI subjects differentiated based on imaging status.
**Note:** The red line indicates the median value; the dashed black line indicates the mean value; the top and bottom of the blue box are the 25th and 75th percentiles, respectively; the red asterisks were considered outliers (more than 1.5 times the interquartile range).
**Abbreviations:** CSSS, Concussion Symptom Severity Score; TBI, traumatic brain injury.

**Table 4** TBI CSSS for imaging, admission, and length of stay status

| | Number of TBI subjects (N = 148) | Median CSSS | Interquartile range | *P*-value |
|---|---|---|---|---|
| **Brain imaging** | | | | 0.10 |
| None | 47 | 22 | 12.25–36.25 | |
| Normal | 83 | 32 | 18–52.5 | |
| Abnormal | 18 | 27 | 15.5–35.25 | |
| **Admission status** | | | | 0.36 |
| Not admitted | 113 | 30 | 14.5–46 | |
| Admitted | 35 | 25 | 18–33.75 | |

**Abbreviations:** CSSS, Concussion Symptom Severity Score; TBI, traumatic brain injury.

**Table 5** CSSS for TBI subjects based on history of head injury and headache

| | Number of TBI subjects (N = 148) | Median CSSS | Interquartile range | *P*-value |
|---|---|---|---|---|
| **Prior head injury** | | | | 0.090 |
| Yes | 40 | 33 | 17.5–52.5 | |
| No | 108 | 26 | 13.25–39 | |
| **Headache** | | | | 0.010 |
| Yes | 37 | 34.5 | 22.5–70 | |
| No | 110 | 26.5 | 12–38 | |
| Unknown | 1 | 54 | N/A | |

**Abbreviations:** CSSS, Concussion Symptom Severity Score; TBI, traumatic brain injury.

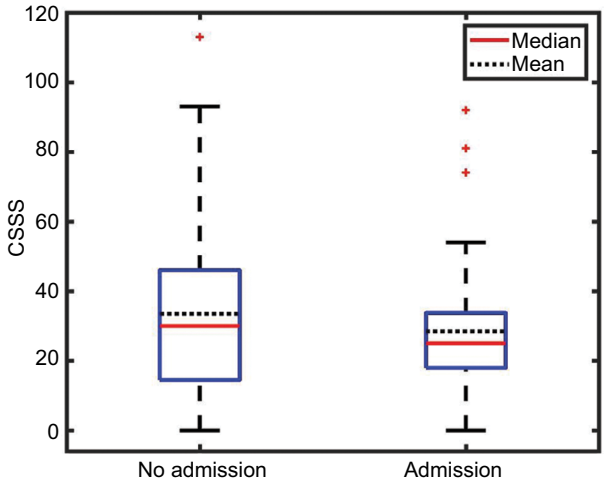


**Figure 4** CSSS for TBI subjects who were not admitted and those who were admitted.
**Note:** The red line indicates the median value; the dashed black line indicates the mean value; the top and bottom of the blue box are the 25th and 75th percentiles, respectively; the red asterisks were considered outliers (more than 1.5 times the interquartile range).
**Abbreviations:** CSSS, Concussion Symptom Severity Score; TBI, traumatic brain injury.

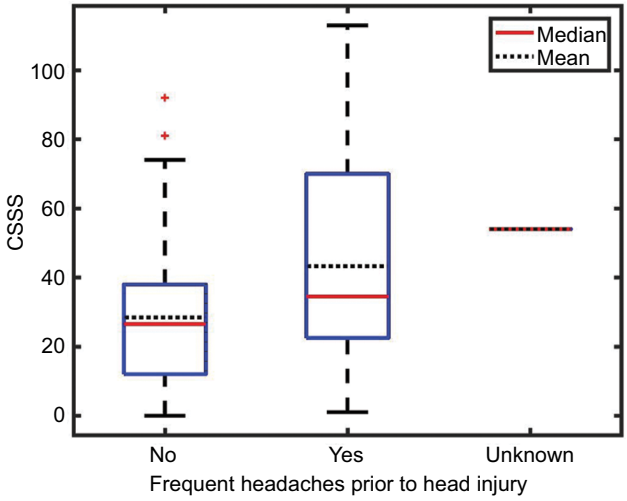


**Figure 6** CSSS of TBI subjects differentiated based on if they had a history of frequent headaches.
**Note:** The red line indicates the median value; the dashed black line indicates the mean value; the top and bottom of the blue box are the 25th and 75th percentiles, respectively; the red asterisks were considered outliers (more than 1.5 times the interquartile range).
**Abbreviations:** CSSS, Concussion Symptom Severity Score; TBI, traumatic brain injury.

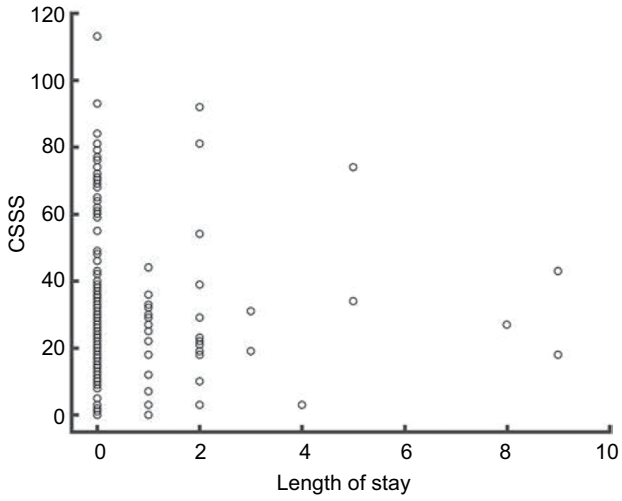


**Figure 5** CSSS of TBI subjects differentiated based on the length of stay.
**Note:** Zero day length of stay means they were not admitted.
**Abbreviations:** CSSS, Concussion Symptom Severity Score; TBI, traumatic brain injury.

in the ED. The CSSS was well tolerated. Other than one lost form, every subject was able to complete the CSSS. The mBESS was well tolerated in the control subjects, but poorly tolerated in the TBI subjects. The pilot study showed that approximately 33% of the TBI subjects could complete the mBESS. On final enrollment, 34.4% of TBI subjects and 96.2% of control subjects could complete the mBESS. Limited research has been done on the mBESS and concussion in non-sport-related settings like the ED. Similar trends of poor tolerance of the mBESS among TBI patients in the ED have been suggested but not confirmed until now.[19]

Our second aim was to determine if CSSS and mBESS could differentiate the brain injury patients and controls in the ED. The CSSS was sensitive to TBI and well tolerated. Comparing with other research, our CSSSs are similar. One study had a mean control CSSS of 4.4 and a median of 1.0 (2.7 and 0, respectively, for our study).[19] This study only looked at ED TBI subjects with CT imaging and did not find a statistical difference between negative and positive CT imaging either. The median for their TBI subjects with negative CT was 35.0 (32 in our study), and the median for positive CT was 45.0 (27 in our study).[19]

While the CSSS was sensitive in identifying a TBI, the CSSS was not specific for TBI. Therefore, the CSSS is susceptible to false positives and patients could appear like they have a TBI based on CSSS but do not. One possible reason is the variability of symptoms reported between subjects. Subjective scales can be different from patient to patient. Pain from other injuries can also elevate the scores on the CSSS questions such as neck pain, "Do not feel right", and trouble falling asleep. Orthopedic patients without a head injury have been shown to have CSSS values higher than control patients but not as high as TBI patients.[19]

In contrast to the CSSS, the subjects who were able to complete the mBESS were not statistically different from control subjects. By comparison, our mean mBESS values were higher than normative data but not entirely different.[26] The mBESS has been validated in athletes, but it does not seem to be appropriate for concussion in a non-sport-related setting as a portion of TBI subjects could not complete the test, and of the portion of TBI subjects who could complete the test, no difference was found. One difference between sport-related concussion and non-sport-related concussion might be a difference in the mechanism of head injury. Athlete studies look mainly at isolated head injuries, while many of the non-sport-related concussions seen in the ED have other injuries present. These other injuries, or the concern for further injury, prevented subjects from completing the mBESS. Another difference between sport-related concussion and non-sport-related concussion are the populations. Sport-related concussions tend to occur in healthy active people who are healthier than the general population. Altogether the mBESS is not an appropriate test for the ED. A majority of subjects could not perform the mBESS, and even those who could were not statistically different from the control subjects.

The post hoc analysis focused on trying to correlate the CSSS and mBESS with severity and hospital outcomes. The severity of a TBI could not be compared with either the mBESS or the CSSS. By using GCS to classify severity, this study comprised almost entirely mild TBI subjects (147/148), with only one moderate TBI. Of the mild TBI subjects, 143 of 147 had a GCS of 15/15. We attempted to compare concussion severity (based on GCS) with mBESS and CSSS results, but it was impossible because nearly all of our subjects had mild TBI.

The CSSS did not help predict other outcomes either. Differences in imaging status, admission status, and hospital length of stay did not correlate with CSSS. The majority of subjects were not admitted and those admitted were mostly admitted for other injuries. History of a head injury did not influence the CSSS, but subjects with a history of headache had higher CSSS scores. While this difference is statistically significant, it may not be clinically significant. The CSSS score does not correlate with severity or hospital outcomes, so knowing that a patient with a history of headaches has a higher CSSS does not help in diagnosis of a TBI or in predicting hospital outcomes.

## Limitations

The first limitation of the study is convenience sampling, which can lead to selection bias. Subjects were recruited only when study personnel were available in the ED. Research personnel were typically available for 12–15 hours per day depending on staffing. This study was a single-center study completed at a university Level I trauma center. Level 2 through four trauma centers may yield different results. The second limitation is the lack of a gold-standard diagnostic tool. Historically, the GCS and CT scanning have been used as a part of the assessment for TBI but are not universal. The GCS in this study came from ED staff, but in general, the GCS has inconsistent timing and may come from a variety of sources: emergency medical services, preliminary trauma evaluation, ED providers, etc. CT scanning is not needed for every TBI evaluation depending on the clinical situation. The third limitation is the study's inability to correlate with severity. Almost all the TBI subjects had mild TBI, and the study was not able to determine if the CSSS correlates with severity. The final limitation of the study is inconsistency in injury patterns from subject to subject. This includes variability in the time since injury and other injuries/illnesses present.

# Conclusion

The CSSS is both sensitive to TBI and well tolerated. The mBESS is poorly tolerated and, among those who can complete the test, not sensitive to TBI in the ED. The majority of TBI subjects were not able to perform the mBESS, and in the TBI subjects who were able to perform, the mBESS did not score significantly different from the control population. Therefore, the mBESS is not an appropriate test for use in the ED. The severity of the TBI could not be determined by the CSSS.

# Disclosure

The authors report no conflicts of interest in this work.

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