

# Functional Assessment of Concussion Tool Application in a Pediatric Concussion Clinic

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## ABSTRACT

**Background:** Traditional concussion symptom scales do not assess function. We piloted a mobile app-based assessment that aims to measure the functional impact of symptoms.

**Methods:** Patients with concussion completed the Functional Assessment of Concussion Tool and traditional symptom scales postinjury.

**Results:** Linear regression assessed the predictive value of the Functional Assessment of Concussion Tool symptom number and function rating compared to scores on 2 traditional symptom scales across 4 symptom domains. The mobile app symptom number predicted scores on traditional symptom scales across domains. The rating score predicted traditional scale scores in 2 domains. The mobile health tool did not predict recovery.

**Discussion:** This mobile health concussion symptom assessment may measure the functional impact of symptoms, though further study is needed.

## BACKGROUND

Mild traumatic brain injury (mTBI), also known as concussion, affects nearly 2 million youth annually, and 70% to 90% of traumatic brain injuries are mTBIs.<sup>1,2</sup> The standard recommended rest period post-concussion is 24 to 48 hours followed by symptom-guided return to activity, and evidence suggests prolonged delays in resuming physical activity are associated with delays in recovery. Patients who have a longer rest period post-injury may spend more time perseverating on their symptoms and less time being physically active.<sup>3</sup> While evidence has moved away from prolonged rest after injury, symptom-sensitive patients may inad-

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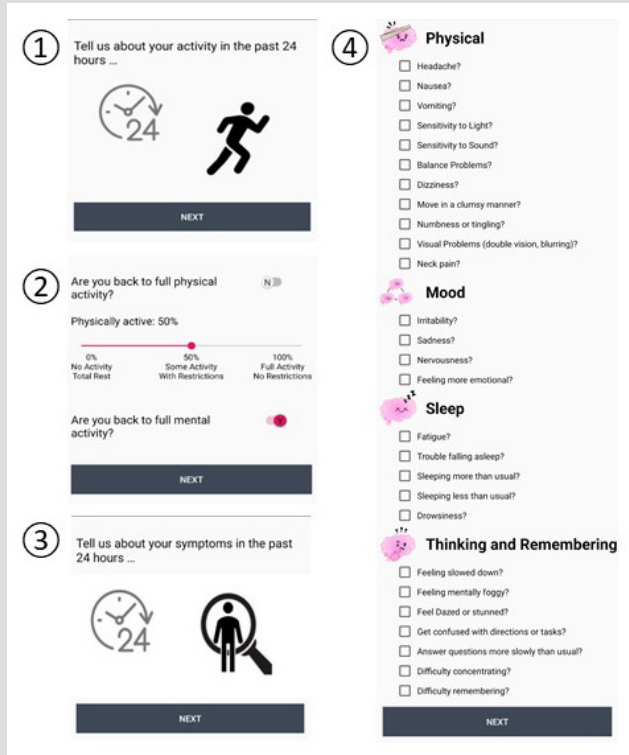
vertently subject themselves to prolonged activity restriction. Traditional symptom scales ask patients to rate the intensity of a wide range of symptoms, which can lead to both under- and overreporting of symptoms. Overreporting could result in a more cautious treatment approach and longer period of activity restriction as symptoms guide return to normal activity. Underreporting could result in premature return to activity.

Mobile health (mHealth) is a tool to monitor mTBI patients' symptoms and activity levels. mHealth is the use of mobile devices for remote patient monitoring to help improve health outcomes and conduct health research.<sup>4</sup> Ninety-one percent

of Americans own a cell phone,<sup>5</sup> and adolescents, in particular, rely on texting to communicate.<sup>6</sup> mHealth can take advantage of technology to provide a convenient way for patients to communicate with health care providers and has been used to assess patient outcomes for other conditions.<sup>7,8</sup>

This study developed and tested an mHealth tool, the Functional Assessment of Concussion Tool (FACT), to measure longitudinal outcomes and recovery following mTBI. The FACT was developed to be easy to use to facilitate remote pediatric patient monitoring. It takes less than 5 minutes to complete and uses a simplified scale to measure the impact of concussion symptoms on daily activities. Traditional symptom assessments ask patients to rate the severity of more than 25 individual symptoms. In contrast, the FACT assessment asks patients to rate how their symptoms affect daily activities using an age-appropriate functional scale modeled on a stoplight (red = symptoms "stopped" me from normal routine; yellow = symptoms "slowed me down;" green = "good to go," did not impact normal routine).

Figure 1. FACT App Screen Shots



(1) Subject is asked about physical and mental activity, which they answer using (2) radio buttons and a slider to report percentage of activity. (3) Subject is then asked to report symptoms and (4) selects symptom they experienced from a checklist of 27 post concussion symptoms. Finally, subject is asked to rate symptoms by each domain (eg, My Physical symptoms) using a stoplight paradigm to determine functional impact of concussion symptoms.

This assessment paradigm is intended to shift patients' focus from symptom counting to symptom reflecting.

This study aims to determine FACT's ability to assess functional outcomes in pediatric patients following acute mTBI and to determine if FACT is better correlated with recovery times compared to traditional symptom scales. We hypothesized that FACT scores would demonstrate a strong correlation with the Sport Concussion Assessment Tool (SCAT)<sup>9,10</sup> and the Post-Concussion Symptom Scale (PCSS)<sup>11</sup> and that FACT scores would have better correlation with recovery by 14 days than the traditional PCSS.

## METHODS

We recruited patients aged 8 to 18 years during their first visit to Children's Hospital of Wisconsin/Medical College of Wisconsin Concussion Clinic after a diagnosis of mTBI. Exclusion criteria included (1) history of brain surgery or moderate to severe traumatic brain injury (Glasgow Coma Score < 14), (2) history of substance abuse, (3) history of major psychiatric disorder, (4) special education, or (5) no access to a smartphone. After obtaining informed consent, patients completed a SCAT3/Child SCAT3, Post-Concussion Symptom Scale (PCSS), and FACT app assessment in the concussion clinic.

The FACT app asked patients to report their physical and mental activity levels, the symptoms they experienced in the last 24 hours, and how their symptoms affected their normal activity. Symptoms were divided into 4 domains: physical, mood, sleep, and thinking and remembering. Patients selected the symptoms they were experiencing in each domain and rated how the symptom domain affected their normal activity using a stoplight scale displayed in Figure 1. The FACT app prompted patients to complete a FACT survey every day for the first 21 days, then every 3 days until 3 months post-injury or achieving FACT recovery. FACT recovery was defined as self-reported return to full activity and "Green" rating in all 4 domains for at least 2 consecutive assessments. Clinical recovery was defined as time from first clinic visit to clearance by sport medicine clinician and was determined by chart review. Parental input on the ease of use of the app was collected on the first 20 patients to optimize usability. For analysis, FACT app rating scores were converted to numeric values (red = 3, yellow = 2, green = 1, respectively). We analyzed both the FACT number of symptoms and FACT ratings of symptoms.

A linear regression model (simple and multiple) was used to determine whether the number of initial FACT symptoms reported and FACT rating across all 4 domains could predict initial SCAT3 and PCSS scores. We used a Cox proportional hazards model to evaluate predictive values of initial SCAT3, PCSS, FACT, and FACT ratings adjusted for gender effect on time to recovery (FACT and clinical).

## RESULTS

We recruited 27 patients. Two-thirds were female and the mean age was 14.56 years. Sports were the most common mechanism of injury (16/27 patients), and median time from injury to first clinic visit was 11 days (interquartile range 6.5-17.5). Mean time to FACT recovery was 31.27 days (n=11), and mean time to clinical recovery was 46.67 days (n=24; 11 cleared during last clinic visit, 13 cleared in phone follow-up after last visit). Mean initial PCSS score was 26 (n=26; one did not complete), and mean SCAT3 score was 29.8 (n=25; two did not complete). Mean total FACT rating on the initial FACT assessment was 7.48 (n=27). The most common symptoms reported on the initial FACT assessment were in the physical and thinking and remembering domains, with more than two-thirds of patients reporting a headache and difficulty concentrating.

The total number of initial FACT symptoms reported was predictive of the total initial SCAT and PCSS scores and SCAT and PCSS scores in the physical, mood, sleep, and thinking and remembering domains ( $P < 0.03$ ). The total FACT rating score was predictive of total SCAT and PCSS scores ( $P < 0.01$ ) (Figure 2) and SCAT and PCSS scores in the mood and thinking and remembering domains ( $P < 0.02$ ) using simple linear regression (Figure 3).

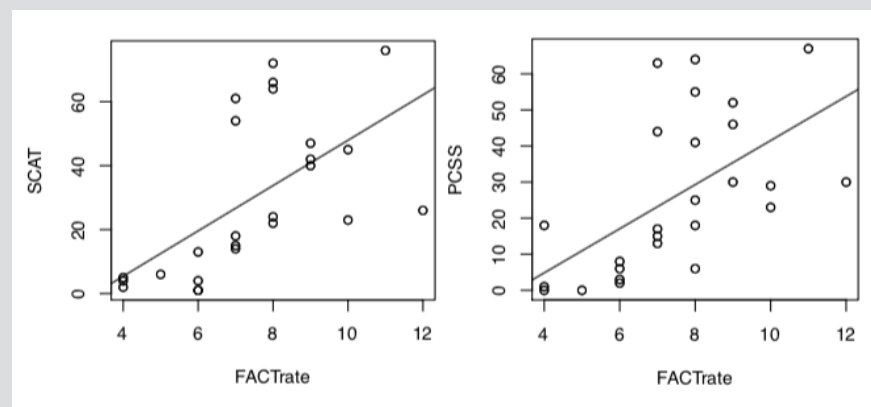
Multiple linear regression models were used to evaluate if the total number of FACT symptoms was predictive of initial SCAT or PCSS scores after adjusting for the FACT rating. The number of initial FACT symptoms was a significant predictor of the total initial SCAT and PCSS scores; the initial SCAT scores in the physical, mood, sleep, and thinking and remembering domains ( $P < 0.01$ ); and in the initial PCSS scores in the physical, mood, and thinking and remembering domains ( $P < 0.01$ ). However, the FACT rating score was not a statistically significant predictor of any SCAT or PCSS scores in the multiple linear regression models.

We have compared predictive properties of initial SCAT, FACT, FACT rating, and PCSS for each of their domains and the total scores. For the times to event (time to FACT recovery and time to clinical recovery), gender was the only significant predictor. Initial FACT symptom scores and clinical PCSS scores were not significant predictors of recovery when adjusted for gender using Cox proportional hazards models.

## DISCUSSION

This is the first study to utilize the FACT assessment paradigm. This preliminary data suggest that FACT symptoms corresponded to traditional symptom scales, as the number of FACT symptoms are correlated with SCAT and PCSS scores across all symptom

**Figure 2.** Comparison of Total Functional Assessment of Concussion Tool Rating Score to Traditional Symptom Scales Scores Obtained at Initial Clinic Visit



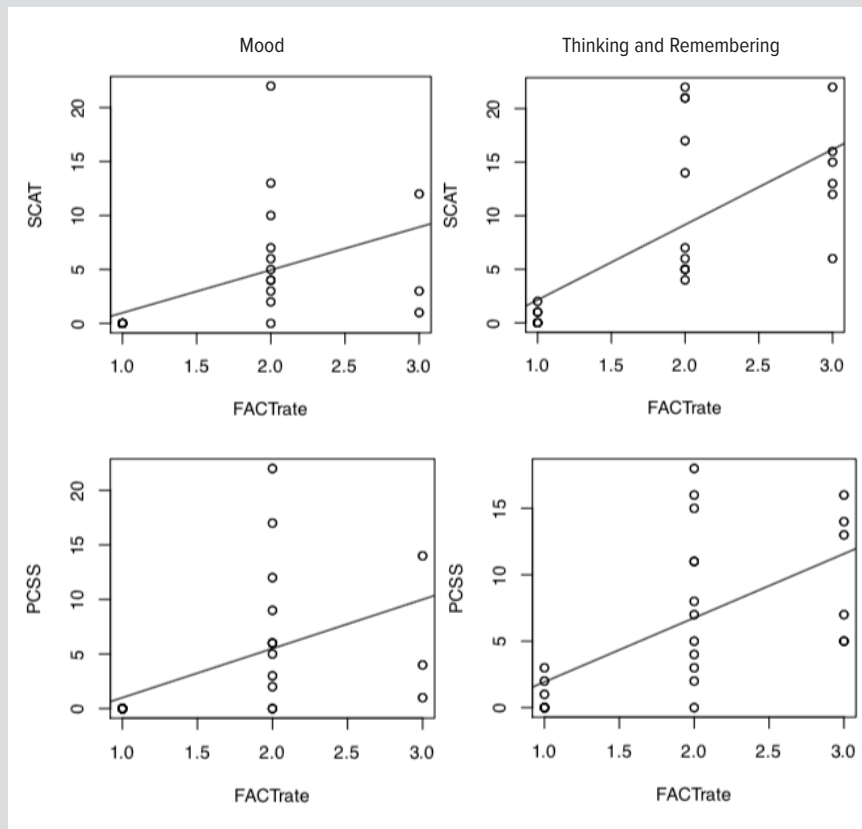
Total Functional Assessment of Concussion Tool rating score (for all 4 domains: physical, mood, sleep, and thinking and remembering) was predictive of Total Sport Concussion Assessment Tool (SCAT) and Post-Concussion Symptom Scale (PCSS) scores ( $P < 0.01$ ).

domains. As the PCSS and SCAT are weighted toward symptom capture, it is not surprising that the number of symptoms on FACT is correlated. Though FACT assessed similar symptoms as the SCAT and PCSS, it uniquely assigned a rating score to the symptoms based on how the symptoms affected daily function. Our findings suggest that as the FACT rating system consolidates symptoms by domain and asks for a functional rating, it measures different components of symptoms compared to traditional symptom scales. This explains why the FACT rating score is a significant predictor of SCAT scores and PCSS across only 2 of 4 domains. The 15-day difference in FACT recovery and clinical recovery may reflect differences in subjective perception versus clinical assessment of recovery or time delays related to scheduling clinic visits for formal concussion clearance.

The PCSS is a standard symptom scale, but it has a number of limitations, including its subjective nature and variable results.<sup>12</sup> As a self-reported scale, some elements of the PCSS, including symptom severity reported on a 0 to 6 scale, may be interpreted differently by individual patients.<sup>13</sup> Additionally, patients without concussion may report concussion symptoms that are due to an unrelated condition, as 1 study showed that patients without concussion endorse symptoms on the PCSS.<sup>13</sup> Many factors influence the number of baseline symptoms reported, including diagnosis of learning disabilities, history of headaches or previous concussion, and others.<sup>13</sup> One study found that athletes with a high number of baseline symptoms on the PCSS had no difference in PCSS scores at 2 to 7 days post-injury.<sup>13</sup> Therefore, knowledge of a patient's baseline and how symptoms affect daily function would be important for interpreting PCSS results, especially when considering symptoms as a guide for recovery.

The FACT's structure may address some of the limitations of the PCSS. While also subject to biases inherent to self-

**Figure 3.** Comparison of Functional Assessment of Concussion Tool Rating Score by Domain to Traditional Symptom Scales Scores by Different Symptom Domains



Functional Assessment of Concussion Tool rating score was predictive of Sport Concussion Assessment Tool (SCAT) and Post-Concussion Symptom Scale (PCSS) scores in the “Mood” and “Thinking and Remembering” domains ( $P < 0.02$  for both SCAT and PCSS).

reported measures, the FACT uses a functional scale focusing on how symptoms affect normal daily activities, which potentially can minimize variability in reporting compared to the PCSS. FACT also accounts for patients who experience symptoms at their baseline, as these regularly experienced symptoms would be present when participating in their normal daily activities. This contrasts with the PCSS, which may capture baseline symptoms that were present before concussion. The initial data in this study support that FACT rating measures a different aspect of symptoms, possibly reflecting the functional effects of concussion symptoms, which is not accounted for in standard symptom scales.

While not replacing other symptom scales, we propose that FACT could be used as a remote monitoring tool that is a more convenient assessment of the patients’ symptoms compared to traditional symptom scales. It allows providers to understand how concussion is affecting a patient. This information could assist providers with management decisions, such as determining follow-up intervals and return-to-activity plans, as well as providing additional information (ie, functional impact of symp-

oms) on recovery status, though by itself it is not a significant predictor of recovery. Future iterations of the FACT app will allow for patients to serially track scores, display recovery progress, and share concussion symptom history with clinicians and school personnel.

The primary limitation of this study is sample size. We recognize that while FACT may address a different component of symptom reporting, the scale is still self-reported and subject to under-/overreporting like the traditional symptom scales. Another important limitation is that while most patients have access to a mobile device,<sup>5</sup> not all children or families in the community do, which may exacerbate health disparities. We do not know how often parents assisted in survey completion or how many families were excluded because they did not have a smartphone. Finally, significant limitations in methodology exist, including temporal comparisons of FACT and traditional symptoms scales. FACT data were obtained daily to every 3 days, while traditional symptom scale data were collected inconsistently at subsequent clinic visits, which limited the ability for comparison of repeated measures. Despite these limitations, the FACT app appears to

be a promising means to provide remote patient monitoring for pediatric concussion recovery. Further investigation with a larger sample is needed to assess the FACT’s strength in measuring the functional component of symptoms and its predictive value in concussion recovery

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