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Measuring Dynamic Symptom Response in Concussion: Children's Exertional Effects Rating Scale (ChEERS)

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Abstract

Objective—To introduce and evaluate a measure of momentary symptom response to cognitive activity, a core feature of concussion.

Setting—Concussion clinic at a large regional children's hospital

Participants—Individuals ages 5–18 years, comprising three clinical groups: Uninjured (n=590), recently concussed but clinically recovered (n=160), and recently concussed but not yet recovered (n=570).

Design—Participants completed pre-test symptom ratings, underwent neurocognitive assessment and completion of questionnaires, then completed post-test ratings. An exertional effects index (EEI) was computed by subtracting pre-test from post-test ratings.

Main Measures—Children's Exertional Effects Rating Scale (ChEERS), which includes four symptoms (Headache, Fatigue, Concentration Problems, and Irritability) rated pre- and post-activity.

Results—The ChEERS was found to have adequate reliability and validity. There were negligible differences in ratings (pre-test and exertional effects) between the Uninjured and Recovered groups, while individuals who were Not-Recovered rated higher levels of pre-test and exertional effects. Base rates showed that an EEI of 4 or more points is rare in individuals who do not have a current concussion.

Conclusion—The ChEERS is a psychometrically sound scale for evaluating momentary symptom increase in response to cognitive activity. Clinicians can use this scale as part of a multi-modal battery for concussion assessment and treatment.

Keywords

mTBI; concussion; pediatric; psychometrics; traumatic brain injury; cognitive exertion; momentary symptom assessment

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Conflicts of interest: none

Introduction

Historically, the clinical assessment of concussion has focused on several key components including symptom status, balance, ocular-motor, and cognitive functioning[1]. Symptom ratings are often a summary of symptom status over a set period of time (e.g., the past 24 hours, the past week) but can also be requested as a momentary report (i.e., symptom level "right now"). Momentary symptom reporting minimizes recall bias and improves sensitivity in detecting symptom change over time[2]. This assessment of symptom change over time ("dynamic assessment") has been used to detect exercise intolerance during injury recovery[3] and as an important criterion for recovery as part of the return to play process[1]. Measuring cognitive activity-induced exacerbation of symptoms, or cognitive exertional effects, may also have clinical utility but has received limited study.

Covassin and colleagues[4] asked high school and college athletes who were three days post-concussion to complete momentary assessment of symptoms before and after a 20-minute cognitive test. They demonstrated statistically significant increases in 6 of 19 symptoms analyzed (e.g., headache, nausea, dizziness, sadness, feeling mentally foggy and visual problems). At ten days post-injury, two symptoms were reported to be significantly worse on average (sadness, difficulty remembering). However, the actual level of symptom worsening on several symptoms was very small, while other symptoms (balance problems, nervousness) improved, raising questions over the clinical utility of these findings. In addition, there was no baseline comparison group to indicate whether these levels of symptom increase would be found in a sample without concussion.

Exertional effects have also been assessed by Meyer and Arnett[5], who administered a standard 22-item symptom scale before and after a 2-hour battery of cognitive tests to two groups of college athletes both pre-injury baseline and post-injury. They found that a greater proportion of post-injury athletes (30%) reported an increase of greater than five points in symptom totals compared with the baseline group (12%). In this study, the scale included items that could not change in the course of a testing session (e.g., sleeping more), which muddies interpretation of the findings. Neither this study nor that of Covassin, et al. included participants younger than high school age, and both studies used a lengthy questionnaire that was originally designed for assessment of symptoms over a period of time (past 24 hours) rather than in the moment.

Silverberg and colleagues[6] took a broad view of measuring cognitive exertional effects, using injured athletes' daily ratings over the first ten days post-injury on a 19-item standard symptom scale. They examined statistically significant "symptom spikes" as a means of understanding the relations between physical and mental activity and dynamic symptom change. They found that significant symptom increases across a 24-hour time period occurred in one-third of this acutely concussed sample. Of that group with symptom spikes, 25% were associated with a sharp increase in mental activity over the preceding 24 hours (e.g., return to school or extracurricular activities), while the absolute level of mental activity on the day of, or the day before, the symptom increase was not related.

Measuring exertional effects following cognitive activity may have implications for understanding treatment and recovery after concussion. Several studies have reported that higher levels of mental activity after concussion may result in increased symptoms and prolonged duration of recovery[7,8] although results are mixed[6]. This dynamic symptom assessment approach after mental activity has been used in other studies as well, with small but significant associations with school outcomes in youth[9].

In sum, there is emerging evidence that symptom exacerbation with cognitive activity can occur post-concussion, with one study showing that it occurs at higher rates in individuals with concussion versus no injury, and that high levels of exertional effects may be associated with more severe overall symptoms or prolonged recovery. It is notable that symptom changes in these studies have typically utilized a comprehensive symptom scale originally developed as a summary measure of severity of current symptoms, not a momentary assessment of symptoms designed to measure short-term dynamic change.

In the current study, we introduce a measure designed specifically for the purpose of momentary symptom assessment to measure acute changes in symptoms in response to activity. Through a series of analyses of three different clinical groups (uninjured, recently concussed but clinically recovered, and recently concussed and not yet recovered), we evaluated the psychometric properties of the scale. Internal consistency reliability of the scale and the correlation of ratings at pre- and post-test were examined. We then established construct validity: convergent, divergent, and group differences. Finally, we examined the clinical utility of the measure by presenting base rates of pre-test symptom endorsement and change scores within each group.

Method

Participants

Children and adolescents, ages 5–18 years, who completed either pre-concussion (“baseline”) or post-concussion evaluation at a large regional children’s hospital and whose data were archived for research use participated in this study. Inclusion criteria were: completed ratings on all four cognitive exertion symptoms at pre- and post-testing, and first post-injury visit within 21 days of injury. Exclusion criteria were: multiple cognitive exertion ratings were >3 standard deviations from the group mean (outlier), diagnosis of Pervasive Developmental Disorder, Autism, or Intellectual Disability, as these disorders could affect an individual’s ability to rate their internal states reliably. Presence of other psychiatric or learning disabilities did not constitute grounds for exclusion, in order to provide a representative sample of youth. No differences were found on key variables (e.g., gender, time since injury) between included participants versus excluded, except that 5–7 year-olds were more likely to be excluded than older participants.

This retrospective study design was approved by the institutional review board. Parents and 18-year-olds provided consent for participation, and minors provided assent.

Uninjured sample—The uninjured group of participants comprised children and adolescents who requested pre-concussion baseline testing (“Uninjured” group). The uninjured group (n=590) was a random selection from a pool of 3826 participants with the same distribution of male/female and age bands as the Not-Recovered group (below); within the 5–7 year-old age group, participants were selected at a 2:1 ratio to increase sample size. There were no significant differences on exertion ratings or demographic factors between Uninjured participants who were selected and not selected.

Concussion sample—Diagnosis of concussion was made and/or confirmed by the treating clinician using AAN clinical criteria[10]. These participants were divided into two clinical groups: those who were "Recovered" (n=160) and those who were "Not-Recovered" (n=570). Determination of recovery status was made by the treating clinician as part of the clinical assessment (i.e., independent of this study design) based on assessment of symptoms, cognitive performance, level of participation in daily activities, and other clinical information.

Demographic information—Basic demographic information was collected (including age, gender, race, ethnicity), along with various mental health and medical diagnoses/problems (including anxiety, depression, attention deficit/hyperactivity disorder, learning disability, and migraines) through interview and parent-completed questionnaires. See Table 1 for demographic information in all three groups, and Table 2 for injury characteristics of the concussion groups.

Measures

Children's Exertional Effects Rating Scale (ChEERS)—Each participant completed ratings on four symptoms (Headache, Fatigue, Concentration Problems, and Irritability) before and after completing neurocognitive testing. These four items were chosen to represent each of the four factors of concussion symptoms on the Post Concussion Symptom Inventory (PCSI)[11]. Each symptom was rated on a Guttman scale ranging from 0 (not experiencing symptom) to 10 (severe). Each numeric rating scale was accompanied by cartoon faces to anchor the options and provide additional context for ratings. See Appendix 1 for a sample rating sheet and administration instructions.

Three scores were calculated for each participant: *total pre-* and *post-test scores* were computed by summing ratings for the four symptoms, and *the exertional effects index (EEI)* was calculated by subtracting the total pre-test rating from the total post-test rating; a positive EEI represented an increase in symptoms.

Post Concussion Symptom Inventory (PCSI)[11]—The PCSI is a validated pediatric concussion symptom checklist, with different forms for self-report for ages 5–7, 8–12, and 13–18. Total scores were used.

Cognitive Exertion Procedure

Participants in all three groups first completed pre-test ChEERS ratings, then underwent neurocognitive assessment and completion of questionnaires (including the PCSI), followed by the completion of the post-test ChEERS ratings.

The exact content of the session (i.e., which neurocognitve tests and questionnaires were administered) varied by clinician preference, including computerized and/or paper pencil neurocognitive measures, plus one or more questionnaires. Given these differences, session duration also varied. The average session duration was 32.6 minutes (SD = 10.5, range 16–94 minutes, interquartile range = 25–37 minutes).

Analysis

Data was first screened to ensure no systematic differences in ratings based on test session variables. In the Uninjured group, there were no differences in ChEERS ratings on individual symptoms or total scores between those tested individually versus those tested in groups (all $p > .24$). Within the injured groups, there were no differences in total change score associated with type of test completed (computerized vs paper/pencil, $p > .05$). Across groups, there were no significant correlations between duration of test session and total change score (all $p > .10$).

Reliability—To address the reliability of the scale, internal consistency reliability of the four symptoms was computed within each injury group. Due to low expected endorsement in the Uninjured and Recovered groups, we hypothesized that internal consistency would be highest in the Not-Recovered group. Second, to assess the within-session stability of ratings, Pearson's correlations of pre- and post-test ratings were computed within each injury group by age band.

Validity—Three lines of evidence for validity were examined: convergent, divergent, and group differences. Convergent validity coefficients were calculated as the correlations between the pre-test ChEERS ratings and the total score on an established symptom rating scale, the PCSI[11]. We hypothesized that there would be a significant, positive correlation in each group, demonstrating that the ChEERS pre-test is an adequate measure of initial symptom status.

To establish divergent validity, correlations between the EEI and the PCSI in each group (i.e., the divergent correlations) were calculated and compared to the convergent validity coefficients using Fisher's r-to-z transformation, using an online calculator[12]. We hypothesized that divergent correlations would be significantly smaller than convergent, particularly in the Not-Recovered group, showing that the EEI (*change in symptoms*) is a construct distinct from overall symptom status.

Group differences: To evaluate group differences, a mixed within (time: pre- and post-ratings)/between (group: Uninjured, Recovered, Not-Recovered) subjects ANOVA was conducted. Three sets of planned comparisons were calculated for each analysis: (1) group differences on pre-test ratings (effect of group at pre-test), (2a) pre- to post-test change within each group (effect of time in each group), and (2b) group differences in pre- to post-test change (time × group interaction). Bonferroni correction was used to control family-wise Type I error rate for these three sets of planned comparisons, with an adjusted alpha of .05/3 = .017. Cohen's d effect sizes were calculated to better characterize the group differences, using the standard deviation of the Uninjured group. We hypothesized that the group differences would consistently show that the Not-Recovered group had higher ratings and EEIs than the Recovered and Uninjured groups, which were hypothesized to be similar to (i.e., not statistically significantly different from) one another.

As a follow-up, these analyses were conducted within each age band (5–7 years, 8–12, and 13–18), to determine whether the ChEERS discriminates between injury groups at all ages.

Base rates—To establish the clinical utility of the ChEERS, base rates of pre-test and EEI ratings were constructed for each of the three injury groups.

Results

Reliability—The internal consistency reliability (Cronbach's alpha) of the four items ranged from .48 to .77 for pre-test ratings and from .60 to .80 on post-test (see Table 3). These were lower than optimal, but not completely unexpected for a scale with only four items, and nearly all symptoms had corrected item-total correlations > .30. As expected, estimates in the Not-Recovered group were stronger than in the Recovered and Uninjured groups.

Within-session stability of ratings (correlating pre- with post-test ratings) of the 4-symptom Total Score in the Uninjured group was $r = .81$, $p < .001$ (see Table 3). Examination within each age band revealed the 8–12 and 13–18 year-olds (both $r = .81$) to exhibit higher stability compared to 5–7 year-olds ($r = .59$). In this younger age band, ratings of headache were the least stable of the four symptoms. Correlation coefficients were strong in both the Recovered ($r = .84$) and Not-Recovered ($r = .80$) groups (see Table 3), with similar coefficients across age bands.

Validity—Validity of ratings was conducted via correlations of the ChEERS ratings with the broader, standard symptom scale (PCSI) within each of the three groups. Since the PCSI forms differ in their content and scaling by age band, correlations were conducted separately within each of the three age bands.

Convergent validity: The correlations between the pre-test ChEERS ratings and the total score on the PCSI were significant in almost every group (see Table 4). Correlations were generally strong ($r > .60$) as hypothesized. The only exceptions were the two groups with the most restricted score ranges (5–7 and 8–12 year-olds in the Recovered group).

Divergent validity: The correlations between the ChEERS EEI and the total score on the PCSI were generally small and non-significant in each group (r range −.19–.38; see Table 4) as hypothesized. Comparisons between the convergent and divergent validity coefficients, computed with Fisher r-to-z comparisons, showed no significant differences in 5–7 year-olds (*p-values* > .07), but convergent correlations were significantly higher than divergent in 8–12 and 13–18 year-olds in all three injury groups, (all $p < .005$) as hypothesized. This finding indicated that there was a stronger relation between pre-test ChEERS and the PCSI than between the ChEERS EEI (i.e., change score) and the PCSI in older children and adolescents in all three injury groups.

Group differences: Mixed within/between subjects ANOVAs found significant main effects of time (pre-to-post, $p < .001$; partial $\eta^2 = .07$) and group ($p < .001$, partial $\eta^2 = .32$), as well as a significant group × time interaction ($p < .001$, partial $\eta^2 = .08$) for pre- and post-test ChEERS ratings (Table 5).

The first set of planned comparisons examined group differences on pre-test ratings, and found no significant difference between the Uninjured and Recovered groups (*ns* after Bonferroni correction) with a small effect size ($d = -0.30$). Mean pre-test ratings in the Not-Recovered group were significantly higher than in the Uninjured and Recovered groups ($p < .001$ for both) as hypothesized, with large effect sizes evidenced between the Not-Recovered and the Uninjured ($d = 1.84$) groups and the Not-Recovered and Recovered ($d = 2.15$) groups.

The second set of planned comparisons evaluated the hypothesized exertional effect - changes from pre- to post-test ratings for each group - by examining the group × time interaction (i.e., group-specific slopes). Results indicated significant mean increases in ratings in the Uninjured and Not-Recovered groups (both $p < .001$) but not in the Recovered group ($p = .45$). Effect sizes for pre- to post-test changes were in line with the hypotheses - negligible for the Uninjured ($d = 0.16$) and Recovered ($d = 0.05$) groups, but medium for the Not-Recovered group ($d = 0.62$). For the third set, tests of simple effects for the group × time interaction indicated that mean slopes were similar between the Uninjured and Recovered groups ($p = .17$), while symptom increases were significantly greater in the Not-Recovered group compared to Uninjured and Recovered (both comparisons $p < .001$), supporting our hypotheses of differences in group-specific slopes. See Figure 1 for a graphical depiction of changes in ChEERS ratings in each group. The same pattern of group differences was found within each age band.

Base rates—Table 6 presents cumulative base rates of ChEERS EEI ratings for each group. When examining this table, three tiers emerge. First, the lower range (EEI negative or 0) indicates no change in symptoms. The majority of individuals in the Uninjured (55%) and Recovered (71%) groups fall in this tier, while only 31% of Not-Recovered individuals report no increase in symptoms. In the second tier (EEI range 1–3, a small change in symptoms) the base rates further diverge between groups. The third tier (EEI ≥ 4, large change in symptoms) is defined by the point at which < 10% of Recovered patients have EEIs that high. In contrast, 33% of individuals in the Not-Recovered group reported an EEI of that magnitude or greater. See Figure 2 for a graphical depiction of the breakdown by tier.

Discussion

Exertional effects following both physical and cognitive activity are documented characteristics of concussion[1]. While studies have shown preliminary evidence that cognitive exertion exists[4,6] and that it occurs at a higher rate in those with concussion versus without[5], these studies have been limited in their approach. Investigations of cognitive exertional effects to date have been limited to populations of adolescents and young adults, using lengthy (~20-item) symptom rating scales that were not intended for dynamic, momentary symptom assessment.

The ChEERS is a momentary symptom assessment measure specifically designed to detect change in symptoms following activity. The scale is focused (four key symptoms) and was designed for use with both children and adolescents. This study demonstrated psychometric properties of the instrument and examined the clinical use of the measure through a comparison of three different groups – two control groups (uninjured, recently concussed but clinically recovered) and the clinically symptomatic group.

Internal consistency of the ChEERS was moderate for pre-test and post-test ratings, but nevertheless adequate, given the small number of items (four) on the scale. Similarly, the strength of cohesiveness of the individual items was greater for the Not-Recovered group, as would be expected when compared with two control samples not anticipated to be experiencing much variability in clinically relevant symptoms (i.e., with range restriction). The ChEERS measure also demonstrated stability over the two time points during the testing session, ranging from .81 to .89 across the three groups.

Several lines of evidence for the validity of the ChEERS measure were established. Convergent validity was demonstrated by the “momentary” pre-test ChEERS being strongly correlated with the “static” symptom PCSI measure in nearly all age bands in all three injury groups. In contrast and as hypothesized, divergent validity was shown by the “dynamic” ChEERS EEI being weakly related to the “static” PCSI ratings, reflecting that momentary symptom exacerbation appears to be a relatively separate phenomenon from general symptom status. Further support for the clinical application of this measure was shown through examining group differences in the EEI. As expected, Uninjured and Recovered individuals had similar EEIs, and both were significantly lower than that of the Not-Recovered group, reflecting the ongoing concussion’s presumed effect on post-activity symptom increase.

Across the age range assessed, it was not unexpected that ratings were more stable and had stronger validity coefficients in the older children and adolescents (ages 8–18) than in younger children (ages 5–7). Developmentally, this younger group is simply less able to identify their internal states and changes in those states. The small number of younger children in our sample precludes firm conclusions, so additional research is needed, and clinical use in the 5–7 year-old age group needs to be undertaken with caution.

In sum, individuals who had not experienced a concussion (Uninjured group) rated pre-test symptoms low and had very little increase in symptoms following cognitive testing. In contrast, individuals who were still actively recovering produced higher pre-test ratings, and their symptoms increased significantly after testing. Recovered individuals rated pre-test symptoms and exacerbations similarly to those of the uninjured group, demonstrating presumed resolution of exertional effects after recovery. These findings illuminate an interesting and unique phenomenon in children with concussion, in that symptoms can increase in response to environmental triggers.

To better quantify these exertional effects for clinical use, base rate tables are presented to demonstrate the frequency of increase in symptoms in clinical (concussion) relative to non-injured and recovered samples. The base rates show that it is not unusual for individuals without concussion to report a slight increase in symptoms after cognitive activity, but that a larger increase is atypical unless one has had a concussion.

Clinical assessment of concussion has included interest in momentary change of symptoms in response to activity, both in terms of tolerance to exercise (e.g., return to play) and symptom management in other activities such as school and work. A psychometrically sound measure to assess this phenomenon has been unavailable until now. This study shows that the ChEERS is a reliable, valid measure for assessing momentary symptoms and their response to cognitive exertion. As noted, the evidence for clinical use is strongest in ages 8–18, with caution urged at this time when used with 5–7 year olds. The phenomenon may have application for symptom management in treatment in addition to assessment. Future research is needed to fully validate the EEI score for clinical use, including assessment of its reliability. There is already support for its validity as a predictor of clinical outcomes [9], but more work can be done.

The data presented herein are limited in part by the cross-sectional nature of the study, which precludes definitive conclusions regarding the course of exertional effects during recovery. Another limitation is that these findings are from a specialty concussion clinic. Although our study population is diverse in terms of including children with certain pre-existing conditions (e.g., anxiety, learning disabilities), these results (particularly the base rates of exertional effects in the clinical groups) may not apply to all settings that treat children who have sustained a concussion. However, the base rates in the Uninjured group are fairly generalizable, as the sample is representative of children who sought baseline testing, and therefore were at risk of concussion.

Greater validation work will further increase the generalizability and applicability of these findings. For example, future studies should examine whether there are gender-based or other group-level differences in EEI. Within mTBI groups, future research should examine whether there are clinical correlates to EEI such as injury characteristics or cognitive profiles. Finally, longitudinal analyses are needed to demonstrate how and when exertional effects change over the course of recovery, and whether those trajectories differ by age or other characteristics.

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Appendix A. Children's Exertional Effects Rating Scale (ChEERS)

Children's Exertional Effects Rating Scale (ChEERS)

NAME: ______________________ DATE: __________ TIME: ______/______

Ratings
PRE / POST

1. Headache: 0 1 2 3 4 5 6 7 8 9 10 ____/____

2. Fatigue: 0 1 2 3 4 5 6 7 8 9 10 ____/____

3. Concentration: 0 1 2 3 4 5 6 7 8 9 10 ____/____

4. Irritability: 0 1 2 3 4 5 6 7 8 9 10 ____/____

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Children's Exertional Effects Rating Scale (ChEERS)

Administration Instructions

Before testing: "Before you start the testing, I want you to rate these symptoms as you are feeling right now. Circle "0" if you are not experiencing the symptom at all right now. Circle "10" if the symptom feels as bad as you can imagine. Or circle a number in between, depending on how you feel."

After testing: "Now that you are done with the testing, I want you to rate these symptoms again as you are feeling right now. Circle the number that rates how you feel."

Scoring Instructions

1. Transfer the Pre and Post Ratings for each symptom to the table below.
2. Subtract the "Pre" rating from the "Post" rating for each symptom to generate a Post-Pre Difference score.
3. Sum all of the Difference scores to produce the Exertional Effects Index (EEI) score.

Symptom Ratings	Pre	Post	Difference (Post-Pre)
1-Headache			
2-Fatigue			
3-Concentration			
4-Irritability			
Total Scores	Pre	Post	Exertional Effects Index (EEI)
Total			

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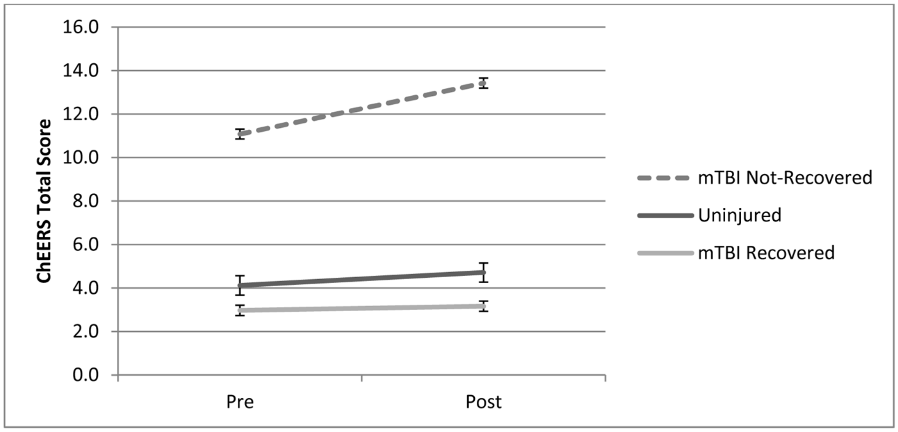

Figure 1. ChEERS ratings by Injury Group

ChEERS = Children's Exertional Effects Rating Scale

mTBI = mild Traumatic Brain Injury (concussion)

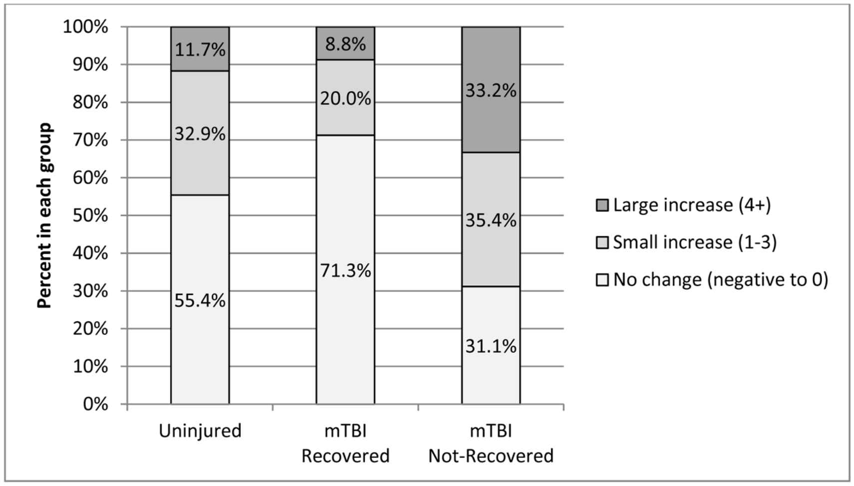

Figure 2. Ranges of Base Rates of ChEERS EEI scores

ChEERS = Children's Exertional Effects Rating Scale

EEI = Exertional Effects Index (post-test rating minus pre-test rating)

mTBI = mild Traumatic Brain Injury (concussion)

Table 1

Demographic Characteristics of Uninjured and mTBI Groups.

N	Uninjured 590		mTBI Recovered 160		mTBI Not-Recovered 570	
	n	%	*n*	%	*n*	%
5–7 years old						
Female	16	40%	6	31%	8	40%
Male	24	60%	13	68%	12	60%
8–12 years old						
Female	50	28%	9	14%	50	28%
Male	130	72%	54	86%	130	72%
13–18 years old *						
Female	165	45%	16	21%	165	45%
Male	205	55%	62	80%	205	55%
Race *						
Black/African American	26	4%	49	31%	88	15%
White/Caucasian	387	66%	79	49%	361	53%
Mixed/Multiracial	10	2%	4	3%	15	3%
Other	31	5%	6	4%	19	3%
Unknown/Did not report	136	23%	22	14%	87	15%
Developmental history						
ADHD *	44	9%	22	14%	92	16%
Learning Disability	19	4%	7	4%	39	7%
Anxiety *	13	3%	10	6%	67	12%
Depression *	7	2%	5	3%	30	5%
Migraine	23	5%	10	6%	44	8%
Age in years * (M (SD))	13.2 (2.76)		12.7 (3.42)		13.8 (2.75)	

*Significant difference between injury groups at $p < .05$.

mTBI = mild Traumatic Brain Injury (concussion)

ADHD = Attention Deficit/Hyperactivity Disorder

Table 2

Injury Characteristics in the mTBI groups.

N	**mTBI Recovered 160**		**mTBI Not-Recovered 570**	
Days since injury				
Mean (SD) *	13.1 (4.56)		11.1 (4.99)	
Median	13		11	
Range	2 – 21		1 – 21	
	n	%	n	%
Injury Cause				
Sports	107	67%	384	67%
Fall	24	15%	79	14%
Motor Vehicle/Pedestrian	11	7%	20	4%
Other	18	11%	87	15%
Lost Consciousness				
Yes	18	11%	70	13%
No	140	89%	481	87%
Unknown/Not reported	0		3	
Neuroimaging Findings				
No Imaging Conducted	91	57%	315	55%
Normal Findings	49	31%	179	31%
Abnormal Findings	6	4%	21	4%
Findings Unknown	1	1%	9	2%
Unknown if imaging conducted	13	8%	46	8%
Number of previous concussions				
None	108	68%	369	67%
1	35	22%	133	24%
2	13	8%	35	6%
3 or more	3	2%	17	3%
Unknown/Not reported	1		16	

*Significant difference between groups, $p < .05$

mTBI = mild Traumatic Brain Injury (concussion)

Table 3

Reliability Statistics for the ChEERS.

N	**Uninjured** 590	**mTBI Recovered** 160	**mTBI Not-Recovered** 570
Internal Consistency Reliability (Cronbach's alpha)			
Pre-test	.61	.48	.77
Post-test	.66	.60	.80
Pre- to Post-test Stability (Pearson's *r*)			
Total score	.81	.84	.89

Note: All correlations significant at $p < .01$

ChEERS = Children's Exertional Effects Rating Scale

mTBI = mild Traumatic Brain Injury (concussion)

Table 4

Convergent and Divergent Validity of the ChEERS and PCSI.

	Convergent: Pre-test with PCSI Total Symptom score[1]			Divergent: EEI with PCSI Total Symptom score[1]			Comparison of convergent and divergent validity[2]		
	Uninjured	mTBI Recovered	mTBI Not-Recovered	Uninjured	mTBI Recovered	mTBI Not-Recovered	Uninjured	mTBI Recovered	mTBI Not-Recovered
Ages 5–7	.63*	.0001	.80*	.20	.23	.38	1.63	−0.64	1.79
Ages 8–12	.65*	.38*	.64*	.10	−.19	.22*	4.83*	2.83*	4.42*
Ages 13–18	.59*	.70*	.77*	.09	.06	.30*	6.18*	5.06*	9.94*

* $p < .01$

[1] Pearson's r

[2] z-values from Fisher's r-to-z tests

Uninjured: 5–7y $n = 27$, 8–12y $n = 124$, 13–18y $n = 246$

mTBI Recovered: 5–7y $n = 18$, 8–12y $n = 57$, 13–18y $n = 80$

mTBI Not-Recovered: 5–7y $n = 18$, 8–12y $n = 157$, 13–18y $n = 375$

ChEERS = Children's Exertional Effects Rating Scale

PCSI = Post-Concussion Symptom Inventory

EEI = Exertional Effects Index (post-test minus pre-test rating)

mTBI = mild Traumatic Brain Injury (concussion)

Table 5

Means and Standard Deviations of ChEERS Ratings.

	Mean (SD)			Effect Size (Cohen's *d*)		
	Uninjured	mTBI Recovered	mTBI Not-Recovered	Uninjured vs. Recovered	Uninjured vs. Not-Recovered	Recovered vs. Not-Recovered
Pre-Test ChEERS Rating	4.12 (3.78)	2.97 (3.50)	11.08 (7.37)	−0.30	1.84*	2.15*
Post-Test ChEERS Rating	4.71 (4.33)	3.16 (3.97)	13.43 (8.69)	−0.36	2.01*	2.37*
EEI	0.59 (2.59)	0.19 (2.15)	2.35 (4.01)	−0.15	0.68*	0.83*

*Post hoc differences between groups at $p < .01$ (after Bonferroni correction)

ChEERS = Children's Exertional Effects Rating Scale

EEI = Exertional Effects Index (post-test minus pre-test rating)

mTBI = mild Traumatic Brain Injury (concussion)

Table 6

Cumulative Base Rates of ChEERS EEI Ratings by Group

		Cumulative Percentages			Group Comparisons: Odds Ratios	
Description of Tier	EEI score	Uninjured	mTBI Recovered	mTBI Not-Recovered	Recovered vs Uninjured	Not-Recovered vs Recovered
1. No increase: Similar rates in all three groups	−11 or higher	100.0%	100.0%	99.8%		
	…					
	−2 or higher	92.7%	92.5%	91.4%	0.8	0.9
	−1 or higher	87.8%	86.3%	88.2%	1.0	1.2
	0 or higher	75.3%	76.9%	82.3%	1.5	1.4
2. Small increase: EEI rates start to deviate	1 or higher	44.6%	28.8%	68.6%	2.7	5.4
	2 or higher	28.0%	18.8%	57.7%	3.5	5.9
	3 or higher	17.1%	12.5%	44.0%	3.8	5.5
3. Large increase: Where < 10% of Recovered group will have an EEI this high	4 or higher	11.7%	8.8%	33.2%	3.7	5.2
	5 or higher	6.4%	5.0%	23.5%	4.5	5.8
	6 or higher	3.7%	1.3%	17.9%	5.6	17.2
	7 or higher	2.9%	0.0%	13.0%	5.0	
	8 or higher	1.9%		8.9%	5.2	
	9 or higher	0.7%		7.0%	11.1	
	10 or higher	0.0%		4.7%		
	…					
	17 or higher			0.4%		
	18 or higher			0.0%		

Note: Cumulative percentages indicate the proportion of individuals in each group who had EEI scores of that level or higher. For example, 44% of our uninjured sample had an EEI of 1 or more, whereas 69% of Not-Recovered individuals had EEIs this high or higher.

The Odds Ratios indicate the relative odds of having an EEI at a certain level or higher. For example, individuals who are Not-Recovered are 5.4 times more likely to have an EEI of 1 or more than individuals in the Uninjured group.

ChEERS = Children's Exertional Effects Rating Scale

EEI = Exertional Effects Index (post-test minus pre-test rating)

mTBI = mild Traumatic Brain Injury (concussion)