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Baseline Performance and Psychometric Properties of the Child Sport Concussion Assessment Tool 3 (Child-SCAT3) in 5-13 Year-Old Athletes

Lindsay D. Nelson, PhD^{1,2}, Michelle M. Loman, PhD², Ashley A. LaRoche, BS¹, Robyn E. Furger, MA¹, and Michael A. McCrea, PhD^{1,2}

¹Department of Neurosurgery, Medical College of Wisconsin, Milwaukee WI

²Department of Neurology, Medical College of Wisconsin, Milwaukee WI

Abstract

Objective—To determine the normative, baseline performance and psychometric properties of the Child Sport Concussion Assessment Tool 3 (Child-SCAT3) in 5-13 year-old athletes.

Design—Cross-sectional study.

Setting—Practice fields.

Participants—Contact sport athletes (N = 155) 5-13 years old.

Independent Variables—Age, gender, verbal intellectual functioning (receptive vocabulary)

Main Outcome Measures—Child-SCAT3: self- and parent-reported symptoms, cognitive performance (child form of the standardized assessment of concussion; SAC-C), and balance (modified balance error scoring system, mBESS-C; tandem gait). A subset of the sample repeated the Child-SCAT3 at another date. Some subjects also completed the Adult-SCAT3 version of the symptom checklist and mBESS.

Results—Small to medium-sized effects of age were observed on all Child-SCAT3 components. Effects of gender and receptive vocabulary were observed on select components of the SCAT3. Younger age and lower receptive vocabulary were independently associated with greater symptom endorsement, yet parents rated higher symptom burden for older children. Internal consistency reliability and stability of symptom ratings was good to excellent. Stability was more modest for SAC-C and tandem gait scores and very poor for mBESS-C scores, perhaps due to restricted variance. Interrater reliability (self- versus parent-rated symptoms) was fair.

Conclusions—The Child-SCAT3 self-report symptom checklist may be inappropriate to administer to younger school-aged children. Some of the age effects observed warrant use of demographically-appropriate norms in Child-SCAT3 interpretation. The findings can provide

Contact: Lindsay Nelson, PhD, 8701 West Watertown Plank Road, Milwaukee WI 53226. PH: 414-955-7308. Fax: 414-955-0115. linelson@mcw.edu.

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guidance for clinicians assessing children of varying ages and point to directions for further development of refined approaches for pediatric concussion assessment.

Keywords

children; youth; concussion; assessment; normative data; child sport concussion assessment tool

Introduction

Sport-related concussion (SRC) is common across ages, with up to 3.8 million children and adults sustaining a sport- or recreation-related concussion annually in the United States.¹ Formalized assessment tools and clinical management guidelines are widely used for adolescent and adult athletes with SRC.²⁻⁵ One of the more commonly-used assessment instruments is the Sport Concussion Assessment Tool 3 (SCAT3), a multidimensional sideline assessment tool validated in high school and collegiate athlete populations.² Yet a major gap exists in the literature on younger athletes (i.e., those in elementary or middle school), who sustain a substantial proportion of SRCs.⁶ As assessment of children with SRC requires unique considerations, there remains a need to develop and validate instruments for pediatric populations.⁷⁻⁹

Those special considerations involve a host of physiologic, developmental, and psychosocial factors that may affect children's risks for and recovery after SRC.^{7,10-16} When assessing children, practicalities such as whether to obtain parent input and how to incorporate developmental expectations into test interpretation need to be considered.⁹ Because of the numerous considerations unique to children, the attendees at the most recent (2012) International Concussion in Sport Group conference concluded that assessments of children with SRC are likely to require involvement from pediatric neuropsychologists.²

It was at this meeting that the group first developed a child version of the SCAT3 (Child-SCAT3) intended for use in athletes 5-12 years-old. The Child-SCAT3 retains the major components of the SCAT3 (e.g., symptom ratings; cognitive and postural stability assessment) while adjusting items for younger children. Although no data have been published on the instrument across all targeted ages, data reporting relative difficulties on components of the SCAT3 for middle versus high school students suggest that the Child-SCAT3 may be needed for this developmental level and below.^{17,18} Additionally, other research on the assessment of children's mild traumatic brain injury symptoms reinforces differences in children's abilities to report their symptoms and the importance of considering parent input.¹⁹

The aim of this study was to demonstrate the typical performance of youth athletes on the Child-SCAT3, including documentation of factors that predict baseline performance and the reliability of scores. A secondary aim was to examine the comparability of symptom ratings gathered through multiple means, including self- and parent-report of Child-SCAT3 symptoms and, for 10-13 year-olds, self-reported symptoms on the Child-SCAT3 versus SCAT3. Our overarching goal was to provide preliminary evidence regarding the utility of the Child-SCAT3 to inform practitioners and facilitate development of evidence-based practice in pediatric concussion assessment.

Methods

Subjects

Participants were 5 to 13-year-old football and soccer players in southeastern Wisconsin who enrolled in the study from October 2013-June 2015. Although the Child-SCAT3 is labeled for use in 5-12 year-old athletes, we also enrolled 13 year-old subjects participating in the middle school teams recruited. After excluding two participants for neurologic disorders associated with cognitive impairment, 155 subjects were available for analysis (Table 1 displays sample characteristics). Other developmental or psychiatric disorders were included to provide findings representative of the population.^A The study was approved by the Institutional Review Board at the Medical College of Wisconsin. Participants received a coupon for a local frozen custard shop for completing the assessment.

Procedures

Athletes were tested at their team practice fields. Research assistants trained in all assessment procedures tested near the fields, spaced adequately to avoid significant distractions between subjects being examined simultaneously. All assessments were conducted one-on-one, with 62.3% of assessments conducted during the subjects' practices, 31.2% before practice, and 6.5% after practice.

Parents completed informed consent, the Child-SCAT3 symptom checklist (Symptoms-C-Parent), and a questionnaire to gather subject and family demographics and subject health history information. All subjects completed the Child-SCAT3² and the Peabody Picture Vocabulary Test – 4 (PPVT-4),²⁰ in counterbalanced order across subjects. Subjects aged 10-13 also completed the SCAT3 symptom checklist, with the order of questionnaire administration counterbalanced (Child-SCAT3, PPVT-4, SCAT3; or SCAT3, PPVT-4, SCAT3). A subset of the sample completed the Child-SCAT3 at a second time point. For all symptom checklist administrations, subjects were provided with a written copy, were verbally read the items, and were allowed to respond by either stating or pointing to their responses.

Assessment Measures

Child-SCAT3—The Child-SCAT3 is comprised of three major components: a symptom checklist, a brief neurocognitive screen (child version of the Standardized Assessment of Concussion, or SAC-C), a balance examination, as well as a 1-point finger-to-nose coordination test. Like its SCAT3 counterpart, the symptom checklist asks subjects to rate their symptoms *now* (if on day of injury; *today* if later)^B but with differing lists of items and response choices. In particular, children rate 20 symptoms on a 0 to 3 (never; rarely; sometimes; often) scale (symptom severity score range 0-60). Parents rate their perception of their children's symptoms over the past 24 hours. Self- and parent-reported Child-SCAT3 symptoms are referred to herein as Symptoms-C-Self and Symptoms-C-Parent, respectively.

^ANotably, the prevalence of these disorders in our sample was similar to or lower than population estimates (American Psychiatric Association, *Diagnostic and Statistical Manual of Mental Disorders*. 5th ed. Washington, DC: American Psychiatric Association).

^BBecause the instruction for baseline testing is not specified, we opted to ask athletes to rate their symptoms “now” to mirror the standard instructions on the SCAT3 form.

The SAC-C produces a 0–30 score with higher scores representing better performance. In comparison to the adult SAC, the SAC-C uses simpler orientation and concentration items (digits backward trials starting at 2 instead of 3 digits; stating days of the week in reverse instead of months of the year). The balance examination is comprised of the double leg stance and tandem stance of the adult mBESS as well as a required tandem gait assessment in lieu of the single leg stance required in the adult mBESS. To determine how children perform on the adult mBESS, the single leg stance trial was administered, allowing computation of both 2-trial child (mBESS-C) and 3-trial adult (mBESS-A) scores. mBESS-C scores range from 0-20 (higher scores reflect more imbalance). The tandem gait assessment requires subjects to walk heel-to-toe down a 3-m line and back and is scored as the fastest time (seconds) across 4 trials. Finally, the coordination examination requires subjects to perform 5 consecutive finger-to-nose trials within 4 seconds and awards credit on pass/fail basis.

SCAT3 Symptom Checklist—The SCAT3 symptom checklist is comprised of 22 items rated on a 0–6 scale, labeled as none (0), mild (1-2), moderate (3-4), and severe (5-6). Subjects rate how they feel *now*. The symptom severity score used in these analyses represents the sum of item-level responses (range 0-132). As athletes self-reported these symptoms, this variable is entitled Symptoms-A-Self below.

PPVT-4—The PPVT-4 assesses receptive vocabulary and was included to estimate general intellectual functioning.²¹ Subjects view four pictures at a time and select the picture that best matches a target word. Age-adjusted standard scores ($M = 100$; $SD = 15$) were used in analyses.

Data Analysis

Age and gender effects—Analyses used age as a continuous variable to maximize statistical power. However, in order to facilitate interpretation of effects, descriptive statistics are presented in the Table 3 collapsing age into discrete groups. Our primary aim was to evaluate the degree to which Child-SCAT3 performance varied by age and gender. Preliminary analyses, however, revealed differences among age levels in PPVT-4 performance (Age main effect $F[1,150] = 4.57$, $p = .034$). Thus, each SCAT3 component was assessed using an Age $\times$ Gender $\times$ PPVT-4 Analysis of Covariance (ANCOVA), with age centered on the sample mean (10) and PPVT-4 standard scores on the normative mean (100). All two-way interactions were tested, but nonsignificant interactions were trimmed in the Results. Effect sizes reported reflect partial eta-squared (η_p^2). Post-hoc tests and descriptive statistics are presented where needed to interpret effects.

Reliability—Internal consistency of the symptom ratings was evaluated using Chronbach's alpha. Test-retest reliability and alternate forms reliability (Symptoms-C-Self vs. Symptoms-A-Self) were computed using Pearson correlations. Interrater reliability (Symptoms-C-Self vs. Symptoms-C-Parent) was evaluated using intraclass correlations (ICC; 2-way, mixed, absolute agreement).

Results

Effects of Age, Gender, and PPVT-4 Performance

Symptoms—Table 2 displays results of the Age $\times$ Gender $\times$ PPVT-4 ANCOVAs performed. Table 3 lists descriptive statistics summarizing the performance of the sample as well as each age and gender group. Both self- and parent-rated Child-SCAT3 symptoms were associated with child age, yet in opposite directions—younger children self-reported more symptoms than older children ($\eta_p^2 = .037$), but parents rated more severe symptoms for older than younger children ($\eta_p^2 = .046$). Across the sample, subjects with lower receptive vocabulary skills (PPVT-4 standard score) endorsed more symptoms ($\eta_p^2 = .048$). For the self-reported SCAT3 symptoms (Symptoms-A-Self) rated by 10-13 year olds, an interaction between age and gender was present such that a main effect of age was present for females but not males (female age $F[1,26] = 6.98$, $p = .014$ versus male age $F[1,73] = 1.87$, $p = .176$), with older females reporting greater symptom burden than younger females ($\eta_p^2 = .205$).

Cognition—Age predicted all SAC-C measures: older subjects performed better on SAC Total ($\eta_p^2 = .251$), Orientation ($\eta_p^2 = .150$), Immediate Memory ($\eta_p^2 = .142$), and Concentration ($\eta_p^2 = .144$) subscales. The Orientation age effect was restricted to the “date” item ($p = .002$, versus other item-level p s $> .177$): the date was correctly reported by 52% of 5-7 year olds, 75% of 8-9 year olds, 73% of 10-11 year olds, and 87% of 12-13 year olds. For SAC-C Total and Orientation scales, Gender $\times$ PPVT-4 interactions were present such that PPVT-4 performance was positively associated with performance on these SAC-C components for males only ($\eta_p^2 = .309$; versus female $\eta_p^2 = .007$). Main effects of PPVT-4 performance were significant for Immediate Memory ($\eta_p^2 = .147$), Concentration ($\eta_p^2 = .031$), and Delayed Recall ($\eta_p^2 = .057$) subtests, with higher PPVT-4 score associated with better performance.

Balance—Main effects of gender were present for both mBESS-C ($\eta_p^2 = .061$) and mBESS-A ($\eta_p^2 = .192$; females performed better than males). Older athletes performed better than younger athletes on the mBESS-C ($\eta_p^2 = .082$), although the main effect of age on mBESS-A was nonsignificant ($\eta_p^2 = .022$). Time to complete tandem gait only demonstrated a significant age effect, with faster times associated with older ages ($\eta_p^2 = .136$). PPVT-4 performance was unrelated to balance.

Coordination—Only 8 subjects (5.2%) failed to achieve a passing score on the finger-to-nose examination, so findings on this measure are reported in descriptive terms. These subjects ranged in age from 7 to 12 and the gender distribution was similar to that of the overall sample (78% male).

Effects of Other Demographic Variables

Exploratory analyses (one-way ANOVAs) were undertaken to evaluate whether other demographic and procedural variables predicted Child-SCAT3 measures. These results are preliminary based on the small samples sizes of subgroups but were thought to be of clinical interest. Variables with frequencies ≤ 5 were not examined. Race (White vs. Nonwhite) and

ethnicity (Hispanic vs. Nonhispanic) were unrelated to any Child-SCAT3 component (p s > .092). History of non-migraine headaches was associated with higher Child-SCAT3 symptom ratings both for self-report (headache history vs. none M s [SD s] = 14.69 [7.45] vs. 10.33 [7.99], p = .039) and parent report (M s [SD s] = 17.07 [9.35] vs. 7.23 [7.74], p < .001). History of concussion was modestly associated with higher Symptoms-A-Parent scores (with versus without concussion history M s [SD s] = 12.00 [9.04] vs. 7.85 [8.32], p = .046). Sport demonstrated significant effects on SAC-C Orientation and mBESS-A scores, even after accounting for group differences in age and gender. In particular, soccer (vs. football) players performed somewhat better on Orientation (M [SD] = 3.71 [.62] versus 3.46 [.65], p = .030 [η_p^2 = .031]) and the mBESS-A (M [SD] = 1.99 [2.47] versus 5.58 [2.98], p < .001 [η_p^2 = .147]).

When testing occurred (before, during, or after practice) was unrelated to symptoms or balance, although it was associated with some SAC-C scores. In particular, small effects of administration time were observed on SAC-C Total (p = .001, η_p^2 = .083), Orientation (p = .023, η_p^2 = .049), Immediate Memory (p = .046, η_p^2 = .040), and Concentration scales (p = .014, η_p^2 = .055; Delayed Recall p = .124, η_p^2 = .027). Follow-up pairwise tests revealed the same pattern of findings across subscales, with lower performance on SAC-C when administered during versus before practice.

Reliability Analyses

Internal consistency of symptom ratings—The internal consistency of Child-SCAT3 symptom ratings was good for self-ratings (Chronbach's alpha = .89) and excellent for parent ratings (alpha = .93). Internal consistency of self-reported SCAT3 symptoms was excellent (alpha = .94).^C

Test-retest reliability—A subsample of 57 athletes (ages 9-13; 84.2% male) completed the Child-SCAT3 a second time (test-retest interval M = 64.3 days, SD = 62.9, range 14-208). Stability was good for Symptom-C-Self ratings (Pearson r = .77), modest for the SAC-C total score (r = .50) and tandem gait (r = .46), and poor for mBESS-C (r = .02).^D

Interrater and alternate forms reliability of symptom severity—Interrater reliability (Symptoms-C-Self vs. Symptoms-C-Parent) was fair (ICC = .35). Alternate forms reliability (Symptoms-C-Self vs. Symptoms-A-Self) was stronger, albeit still modest (r = .56).

Discussion

The current study provided preliminary data regarding the normative performance and psychometric properties of the Child-SCAT3 in athletes ages 5-13. Statistically significant,

^CChronbach's alpha for the Child-SCAT3-Self in this older (10-13 year old) cohort was nearly identical to that of the overall sample (alpha = .90).

^DBased on a recommendation that children be baseline tested every 6 months due to ongoing development (McCrory et al., *Br J Sports Med*, 38[5], 516-519), we recomputed stability coefficients for those 48 athletes whose test-retest interval was within 6 months. This had no marked effect on the stability coefficients reported: 6-month stability for symptom, SAC-C, tandem gait, and mBESS-C scores r = .76, .51, .48, and -.02, respectively.

small to medium effects of age were observed on all Child-SCAT3 components (self- and parent-reported symptoms, SAC-C, and balance), whereas select effects of gender and verbal intellectual functioning were observed on select components. Data on the adult SCAT3 symptom checklist and mBESS-A revealed that older (vs. younger) females reported more symptoms (among the 10-13 year olds who received this checklist) and female athletes performed better on the mBESS-A than males (across all ages). Good to excellent internal consistency reliability was observed across symptom rating scales and modes of administration (Symptoms-C-Self, Symptoms-C-Parent, Symptoms-A-Self). Test-retest reliability of the Child-SCAT3 facets was more variable, with good stability of self-reported symptom ratings but modest stability of SAC-C scores and tandem gait and very poor mBESS-C stability. It is possible that range restriction contributed to the low stability of mBESS-C scores ($M[SD] = 1.36 [1.60]$ errors).

It is worth drawing attention to the fact that the effects of age and gender reported, although statistically significant, are of variable degrees of relevance in terms of clinical importance. For example, the effect of age on baseline symptom score appears to be driven primarily by elevated ratings in the 5-7 year-old cohort, with relatively small differences in mean symptom score (about 1.5 points) between the 8-13 year-old cohorts. Table 3 can be referenced to determine the raw magnitude of group differences across measures. The table also highlights the common finding that baseline (pre-SRC) symptom severity ratings are non-zero (9.5-13.5 depending on the age group in this sample), thereby providing a normative reference to facilitate clinicians' decisions about when concussed athletes' have experienced recovery from SRC-related symptoms.

Interestingly, the direction of the effects of age on self- versus parent-reported Child-SCAT3 symptoms was in opposite directions: parents reported greater symptom burden for older versus younger children, while younger children self-reported more symptoms than older children. At a minimum, this highlights the importance of obtaining both parent and child symptom reports and developing age-appropriate norms for both modes of symptom assessment. Controlling for age, children with lower verbal intellectual functioning (i.e., receptive vocabulary) also self-reported greater symptom burden. Taken together, these findings imply that children with more limited vocabularies manifested more acquiescent endorsement of symptoms.

These findings raise the possibility that the symptom information provided by our younger subjects was of questionable validity, a possibility consistent with a broader literature identifying challenges in obtaining accurate reports from young children. There is an inherent social pressure for children to respond to adults' questions, a phenomenon thought to account for why they provide answers to knowingly bizarre questions.²² Children provide especially biased responses to discrete (e.g., yes/no) questions²³⁻²⁶ and have been shown to have difficulty making frequency judgments as required by the Child-SCAT3.^{27,28} Consequently, it is considered best practice when interviewing young children to maximize the use of open-ended questions and engage in pre-interview "ground rules" discussions to allow children to practice saying "I don't know" and asking for clarification.²⁹

The format of the Child-SCAT3 administration and response choices, as well as the unclear developmental level needed to understand item content, may make use of the symptom checklist in its current form challenging for children early in their schooling (perhaps those under 7 at a minimum). Anecdotally, our research team found it confusing to ask children to rate their symptoms *now* on a frequency-based rating scale and reported perceived confusion on the part of 5-6 year olds in particular when rating their symptoms. Although we read all items aloud to subjects, users should be even more cautious when asking children to read the questionnaire themselves (the Flesch-Kincaid reading level varies from grade 0.0 to 9.9 across items, $M = 2.6$).^E The recently developed Postconcussion Symptom Inventory (PCSI) is an example of a measure that considers some of the important nuances of the assessment of young children. Developed through careful consideration of varying abilities of school-aged children and modern psychometric techniques, the PCSI has three different forms (for children aged 5-7, 8-12, and 13-18), with more limited item content and response choices for younger children.¹⁹

Beyond symptom ratings, our findings of at least moderate effects of age on the SAC-C imply that age-appropriate norms are needed. Given the reported data on the adult SCAT3 symptom checklist and the mBESS-A, further study of the SCAT3 in middle school athletes may be valuable. The descriptive statistics provided serve as useful referents to clinicians using the Child-SCAT3; however, these data only represent an initial step toward the development and validation of the instrument for children of varying ages. The limited sample size precluded us from presenting normative performance tables at the level of granularity expected in pediatric populations, and the particular characteristics of our sample (predominantly White, with high-average estimated intellectual ability) may not mirror other populations to a degree needed to use these data as definitive norms. Furthermore, our data support others' findings that athletes' performance can be negatively affected by recent physical exertion and the distracting testing environment characteristic of the sport sideline, implying that future Child-SCAT3 studies should take into account such contextual factors.³⁰⁻³⁴ Finally, as stated earlier, several developmental considerations make use of the current Child-SCAT3 symptom checklist potentially problematic with very young children and underscores the importance of also obtaining parent report, especially for children under 8 or 10 years of age.

Despite these limitations, these findings—representing a well-characterized sample of youth athletes—shed light on a number of factors that appear relevant toward child athletes' performance on the Child-SCAT3 (and components of the SCAT3) and point to the estimated performance level of elementary and middle-school children on the Child-SCAT3. With ongoing refinement and study of the instrument and careful consideration of developmental factors, the field will move in the important direction of improving available methods for assessment of youth athletes.

^EFlesch-Kincaid values derived using Microsoft Word 2010.

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References

1. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trauma Rehabil.* 2006; 21:375–378. [PubMed: 16983222]
2. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Br J Sports Med.* 2013; 47:250–258. [PubMed: 23479479]
3. Herring SA, Cantu RC, Guskiewicz KM, et al. Concussion (mild traumatic brain injury) and the team physician: A consensus statement--2011 update. *Med Sci Sports Exerc.* 2011; 43:2412–2422. [PubMed: 22089299]
4. Giza CC, Kutcher JS, Ashwal S, et al. Summary of evidence-based guideline update: Evaluation and management of concussion in sports: Report of the Guideline Development Subcommittee of the American Academy of Neurology. *Neurology.* 2013; 80:2250–2257. [PubMed: 23508730]
5. Broglio SP, Cantu RC, Gioia GA, et al. National Athletic Trainers' Association position statement: management of sport concussion. *J Athl Train.* 2014; 49:245–265. [PubMed: 24601910]
6. Bakhos LL, Lockhart GR, Myers R, Linakis JG. Emergency department visits for concussion in young child athletes. *Pediatrics.* 2010; 126:e550–556. [PubMed: 20805145]
7. McCrory P, Collie A, Anderson V, Davis G. Can we manage sport related concussion in children the same as in adults? *Br J Sports Med.* 2004; 38:516–519. [PubMed: 15388528]
8. Gioia GA, Schneider JC, Vaughan CG, Isquith PK. Which symptom assessments and approaches are uniquely appropriate for paediatric concussion? *Br J Sports Med.* 2009; 43(1):i13–22. [PubMed: 19433419]
9. Kirkwood MW, Yeates KO, Wilson PE. Pediatric sport-related concussion: A review of the clinical management of an oft-neglected population. *Pediatrics.* 2006; 117:1359–1371. [PubMed: 16585334]
10. Goldsmith W, Plunkett J. A biomechanical analysis of the causes of traumatic brain injury in infants and children. *Am J Forensic Med Pathol.* 2004; 25:89–100. [PubMed: 15166757]
11. Ommaya AK, Goldsmith W, Thibault L. Biomechanics and neuropathology of adult and paediatric head injury. *Br J Neurosurg.* 2002; 16:220–242. [PubMed: 12201393]
12. Bauer R, Fritz H. Pathophysiology of traumatic injury in the developing brain: an introduction and short update. *Exp Toxicol Pathol.* 2004; 56:65–73. [PubMed: 15581277]
13. Anderson V, Catroppa C, Morse S, Haritou F, Rosenfeld J. Outcome from mild head injury in young children: A prospective study. *J Clin Exp Neuropsychol.* 2001; 23:705–717. [PubMed: 11910538]
14. Bruce DA, Alavi A, Bilaniuk L, Dolinskas C, Obrist W, Uzzell B. Diffuse cerebral swelling following head injuries in children: the syndrome of “malignant brain edema”. *J Neurosurg.* 1981; 54:170–178. [PubMed: 7452330]
15. Pickles W. Acute general edema of the brain in children with head injuries. *N Engl J Med.* 1950; 242:607–611. [PubMed: 15412680]
16. McCrory P, Berkovic SF. Second impact syndrome. *Neurology.* 1998; 50:677–683. [PubMed: 9521255]
17. Glaviano NR, Benson S, Goodkin HP, Broshek DK, Saliba S. Baseline SCAT2 assessment of healthy youth student-athletes: Preliminary evidence for the use of the Child-SCAT3 in children younger than 13 years. *Clin J Sport Med.* 2015; 25:373–379. [PubMed: 25318531]

18. Snyder AR, Bauer RM. Health IFFN. A normative study of the sport concussion assessment tool (SCAT2) in children and adolescents. *Clin Neuropsychol.* 2014; 28:1091–1103. [PubMed: 25244434]
19. Sady MD, Vaughan CG, Gioia GA. Psychometric characteristics of the postconcussion symptom inventory in children and adolescents. *Arch Clin Neuropsychol.* 2014; 29:348–363. [PubMed: 24739735]
20. Dunn, LM., Dunn, DM. PPVT-4: Peabody picture vocabulary test. Minneapolis: NCS Pearson, Inc.; 2007.
21. Bell NL, Lassiter KS, Matthews TD, Hutchinson MB. Comparison of the Peabody Picture Vocabulary Test-Third Edition and Wechsler Adult Intelligence Scale-Third Edition with university students. *J Clin Psychol.* 2001; 57:417–422. [PubMed: 11241372]
22. Pratt C. On asking children - and adults - bizarre questions. *First Lang.* 1990; 10:167–175.
23. Brady MS, Poole DA, Warren AR, Jones HR. Young children's responses to yes-no questions: Patterns and problems. *Appl Dev Sci.* 1999; 3
24. Fritzley HV, Lindsay RCL, Lee K. Young children's response tendencies toward yes-no questions concerning actions. *Child Dev.* 2013; 84:711–725. [PubMed: 23106312]
25. Mehrani MB. What is biased? Children's strategies on the structure of yes/no questions? *First Lang.* 2011; 31:214–221.
26. Peterson C, G M. Force-choice: Are forensic interviewers asking the right questions? *Can J Behav Sci.* 2001; 33
27. Harris JF. Knowledge base influences on judgments of frequency of occurrence. *Cogn Dev.* 1990; 5:223–233.
28. Wandrey L, Lyan TD, Quas JA, Friedman WJ. Maltreated children's ability to estimate temporal location and numerosity of placement changes and court visits. *Psychol Public Policy Law.* 2012; 18
29. Brubacher SP, Poole DA, Dickinson JJ. The use of ground rules in investigative interviews with children: A synthesis and call for research. *Dev Rev.* 2015; 36:15–33.
30. Moser RS, Schatz P, Neidzowski K, Ott SD. Group versus individual administration affects baseline neurocognitive test performance. *Am J Sports Med.* 2011; 39:2325–2330. [PubMed: 21828367]
31. Lichtenstein JD, Moser RS, Schatz P. Age and test setting affect the prevalence of invalid baseline scores on neurocognitive tests. *Am J Sports Med.* 2014; 42:479–484. [PubMed: 24243771]
32. Vaughan CG, Gerst EH, Sady MD, Newman JB, Gioia GA. The relation between testing environment and baseline performance in child and adolescent concussion assessment. *Am J Sports Med.* 2014; 42:1716–1723. [PubMed: 24787043]
33. Rahn C, Munkasy BA, Barry Joyner A, Buckley TA. Sideline performance of the Balance Error Scoring System during a live sporting event. *Clin J Sport Med.* 2015; 25:248–253. [PubMed: 25098674]
34. Susco TM, Valovich McLeod TC, Gansneder BM, Shultz SJ. Balance recovers within 20 minutes after exertion as measured by the Balance Error Scoring System. *J Athl Train.* 2004; 39:241–246. [PubMed: 15496993]

Table 1
Sample Characteristics (*N* = 155)

	<i>N</i> (%)
Gender	
Male	100 (64.5%)
Female	55 (35.5%)
Age	
5-7	25 (16.2%)
8-9	24 (15.6%)
10-11	45 (29.2%)
12-13	60 (39.0%)
Race	
White	130 (83.9)
Black	6 (3.9%)
Asian	2 (1.3%)
American Indian/AK Native	1 (0.6%)
Multiracial	8 (5.2%)
Other/Unknown	8 (5.1%)
Ethnicity	
Hispanic	8 (7.0%)
Sport	
Football	105 (67.7%)
Soccer	50 (32.3%)
PPVT-4 SS <i>M</i> (<i>SD</i>)	110.19 (13.45)
ADHD	5 (3.2%)
Learning disability	3 (1.9%)
Autism spectrum	2 (1.3%)
Psychiatric disorder	2 (1.3%)
Non-migraine headaches	16 (10.5%)
Migraine headaches	5 (3.3%)
Prior concussion	19 (12.4%)

Note. AK = Alaska; SS = Standard Score (*M* = 100; *SD* = 15); ADHD = attention deficit-hyperactivity disorder; Parents provided demographic and health history information

Table 2
Effects of Age, Sex, and Verbal Intellectual Functioning (PPVT-4)

	Age		Gender		PPVT		Age × Gender		Gender × PPVT	
	F	p	F	p	F	p	F	p	F	p
Symptoms-C-Self	5.71	.018	.37	.544	7.50	.007				
Symptoms-C-Parent	6.92	.009	.09	.768	.57	.452				
Symptoms-A-Self ^I	3.39	.069	7.49	.007	2.23	.139	7.94	.006		
SAC-C Total	49.69	< .001	2.95	.088	13.94	< .001			7.20	.008
Orientation	26.23	< .001	3.69	.057	4.99	.027			4.96	.027
Immediate Memory	24.57	< .001	3.05	.083	25.64	< .001				
Concentration	25.17	< .001	.02	.878	4.85	.029				
Delayed Recall	4.13	.044	1.34	.249	9.01	.003				
mBESS-C Total	13.33	< .001	9.74	.002	.22	.637				
mBESS-A Total	3.39	.068	35.74	< .001	.34	.560				
Tandem Gait	23.40	< .001	1.29	.259	.55	.461				

Note. Bolded where $p < .05$;

^I administered to children aged 10-13 years old only;

Child-SCAT3 and Adult-SCAT3 refer to symptom severity scores. PPVT = Peabody Picture Vocabulary Test – 4 Standard Score; Symptoms-C-Self and Symptoms-C-Parent reflect Child-SCAT3 symptom severity scores for self- and parent-ratings, respectively. Symptoms-A-Self reflect self-reported symptom severity from the adult SCAT3. SAC-C = Standardized Assessment of Concussion (child form); mBESS = modified Balance Error Scoring System (-C = child form; -A = adult form)

Table 3
Descriptive Statistics for Sample and Stratified by Age and Gender

	Total sample (<i>N</i> = 155)	Age (years)				Gender	
		5-7 (<i>n</i> = 25)	8-9 (<i>n</i> = 24)	10-11 (<i>n</i> = 45)	12-13 (<i>n</i> = 60)	Female (<i>n</i> =55)	Male (<i>n</i> = 100)
Symptoms-C-Self ^A	10.89 (8.04)	13.88 (8.66)	10.63 (6.43)	11.07 (8.23)	9.47 (8.01)	10.82 (8.43)	10.93 (7.86)
Symptoms-C-Parent ^{A,G}	8.38 (8.50)	4.87 (6.01)	7.92 (7.14)	7.70 (7.58)	10.42 (9.96)	8.31 (8.72)	8.41 (8.42)
Symptoms-A-Self ^I	7.14 (10.79)	-	-	8.16 (12.11)	6.40 (9.74)	6.24 (11.60)	7.49 (10.51)
SAC-C Total ^{A,I}	25.18 (2.94)	23.04 (2.91)	25.17 (2.04)	24.67 (3.54)	26.47 (2.04)	25.27 (2.61)	25.12 (3.11)
Orientation ^{A,I}	3.63 (0.63)	3.20 (0.91)	3.71 (0.55)	3.60 (0.54)	3.80 (0.51)	3.69 (0.63)	3.60 (0.64)
Immediate Memory ^A	13.60 (1.52)	12.68 (1.84)	13.87 (0.81)	13.29 (1.83)	14.13 (1.05)	13.69 (1.36)	13.56 (1.60)
Concentration ^A	3.92 (1.05)	3.28 (0.94)	3.63 (1.10)	3.93 (1.03)	4.30 (0.94)	3.80 (1.01)	3.98 (1.07)
Delayed Recall ^A	4.01 (1.19)	3.88 (1.13)	3.91 (1.20)	3.84 (1.48)	4.23 (0.96)	4.09 (0.99)	3.97 (1.30)
mBESS-C Total ^{A,G}	1.36 (1.60)	1.88 (2.09)	1.58 (1.69)	1.36 (1.63)	1.07 (1.27)	0.95 (1.30)	1.59 (1.71)
mBESS-A Total ^G	3.15 (3.13)	1.88 (2.09)	1.67 (1.71)	3.76 (3.70)	3.85 (3.16)	1.25 (1.99)	4.19 (3.15)
Tandem Gait ^A	12.98 (4.43)	16.33 (4.87)	14.45 (5.30)	12.73 (4.10)	11.22 (2.96)	13.89 (4.29)	12.47 (4.44)

Note. Symptoms-C-Self and Symptoms-C-Parent reflect Child-SCAT3 symptom severity scores for self- and parent-ratings, respectively. Symptoms-A-Self reflect self-reported symptom severity from the adult SCAT3. SAC-C = Standardized Assessment of Concussion (child form); mBESS = modified Balance Error Scoring System (-C = child form; -A = adult form);

^A significant main effect of age found on this variable;

^G significant main effect of gender found on this variable.

^I Interactive effect related to age or gender (see Table 2 and prose)