REFINING THE CLINICAL USEFULNESS OF THE CHILD SPORT CONCUSSION ASSESSMENT TOOL 5TH EDITION

by

Patricia M. Kelshaw
A Dissertation
Submitted to the
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of
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in Partial Fulfillment of
The Requirements for the Degree
of
Doctor of Philosophy
Education

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Fairfax, VA

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Spring Semester 2020
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Dedication

In loving memory of Lois M. Kelshaw and Edward J. Sturgeon.

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List of Abbreviations and Symbols

Above Normal .... AN
Advancing Healthcare Initiatives for Underserved Students .... ACHIEVES
Athlete Exposure .... AE
Athletic Trainers .... AT
Attention-Deficit/Hyperactivity Disorder .... ADHD
Area Under the Curve .... AUC
Balance Error Scoring System .... BESS
Below Normal B1N
Broadly Normal .... BN
Centers for Disease Control and Prevention .... CDC
Child Sport Concussion Assessment Tool, 3rd Edition .... Child SCAT3
Child Sport Concussion Assessment Tool, 5th Edition .... Child SCAT5
Chi-Square .... χ^2
Concentration .... Con
Concussion in Sport Group .... CISG
Confidence Interval CI
Delayed Recall .... DR
Digits Backwards .... DB
Effect Size .... *r*
Extremely High .... EH
Extremely Low .... EL
Federation Internationale de Football Association .... FIFA
FIFA – Medical Assessment and Research Centre .... F-MARC
Glasgow Coma Scale .... GCS
Health and Behavior Inventory .... HBI
Healthcare Provider .... HCP
Immediate Memory .... IM
Immediate Post-Concussion Assessment and Cognitive Testing .... ImPACT®
International Ice Hockey Federation .... IIHF
International Olympic Committee .... IOC
Interquartile Range .... IQR
Learning Disorders .... LD
Mean .... M
Median .... Md
Modified Balance Error Scoring System .... mBESS
Normative Classifications .... NC

Pearson Correlation Coefficient .... r_p
Post-Concussion Symptom Scale .... PCSS
Receiver Operating Characteristic .... ROC
Reliable Change Index .... RCI
Single Leg Stance .... SL
Sodium-Potassium .... Na-K
Spearman Correlation Coefficient .... r_s
Sport Concussion Assessment Tool .... SCAT
Sport Concussion Assessment Tool, 2nd Edition SCAT2
Sport Concussion Assessment Tool, 3rd Edition SCAT3
Sports-Related Concussion .... SRC
Standard Assessment of Concussion – Child Version .... SAC-C
Standard Assessment of Concussion .... SAC
Standard Deviation .... SD
Standard Error Difference .... S_{diff}
Standard Error Measure .... SEM
Tandem Leg Stance .... TL
Unusually High .... UH
Unusually Low .... UL

Abstract

REFINING THE CLINICAL USEFULNESS OF THE CHILD SPORT CONCUSSION ASSESSMENT TOOL 5TH EDITION

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George Mason University, 2020

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Our goal, through this program of research, was to improve the evaluation of sports-related concussion in children. To do so, three research studies were conducted using the Child Sport Concussion Assessment Tool, 5th Edition (Child SCAT5) among a diverse cohort of children ages 11 to 13 years participating in public school sponsored sports programs. As such, we aimed to (i) create evidence-based guidance to determine what constitutes typical or "normal" Child SCAT5 performance among healthy, uninjured children; (ii) understand the temporal stability and reliable change of the Child SCAT5 in a healthy, uninjured sample; and (iii) describe the sideline performance of children on the Child SCAT5 who were diagnosed with a concussion. We observed the following: (i) Gender, age, and language spoken at home are associated with baseline performance on multiple components of the Child SCAT5 among middle school students, though the magnitudes of observed differences are small. Normative reference values are

provided for clinicians when interpreting Child SCAT5 scores. (ii) The Child SCAT5 scores had low test-retest reliability over a one-year period. Despite this, we provide the distributions of Child SCAT5 raw score changes upon retesting to aid clinicians in interpreting changes that are uncommon in an uninjured sample. (iii) The Child SCAT5 was useful for measuring the ultra acute effects of concussion in children. Certain symptoms on the symptom scale were more clinically useful for sideline assessment than others. Interpretation methods relying on comparisons of post-injury test scores to baseline preseason scores and normative reference values were both useful for detecting impairment within the concussed middle school sample. However, both had limitations that are important for clinicians to be aware of. In summary, the assessment of concussion in children is complex and requires the careful consideration of multi-dimensional and sometimes contradictory information. As such, the Child SCAT5 should be viewed as tool to gather data that informs clinical judgment and should not be used in isolation to diagnose a concussion. Future research should replicate and extend these findings to include greater time intervals following injury, and larger samples of children, to further refine the assessment of concussion in children.

Chapter One: Introduction

Children who participate in sports enjoy physiological, social, psychological, motor learning, and cognitive benefits.[1] While there are many benefits of sports participation, there is also risk of sports-related injury. Sports-related concussions are among the most common injuries sustained in youth and scholastic sports.[2–10] Concussions are characterized as functional injuries resulting in transient neurological dysfunction, rather than a structural injury to the brain.[11] The Child Sports Concussion Assessment Tool 5th edition (Child SCAT5)[12] is a multi-modal assessment tool used to evaluate subjectively-experienced symptoms, cognitive functioning, and balance following concussion. There are important gaps in the literature regarding the clinical utility of the Child SCAT5. Namely, there have not been: (i) normative studies to determine normal or abnormal Child SCAT5 performance stratified by unique demographic characteristics, (ii) test-retest reliability studies to determine the temporal stability of Child SCAT5 scores over time, or (iii) studies examining the acute effects of concussion, as measured by the Child SCAT5. Moreover, middle school age student-athletes, typically ages 11 to 13, are underrepresented in concussion research. Research informing concussion management strategies is especially important for middle school athletes, because they have between 1.5 and 3 times the incidence of concussion compared to high school athletes [0.75/1,000 athlete exposures (AE)[2] vs 0.24-0.5/1,000

AE[13,14]]. With evidence-based guidance to determine what constitutes typical or “normal” Child SCAT5 performance, an understanding of the temporal stability of Child SCAT5 scores, as well as evidence of acute post-concussion performance, clinicians may be able to better manage concussions within the middle school population.

Statement of the Purpose and Research Questions

The overarching goal of this dissertation is to conduct leading-edge research that comprehensively investigates the clinical usefulness of the Child SCAT5. The three studies comprising this dissertation are summarized below.

Study I. Child Sport Concussion Assessment Tool 5th Edition: Normative Reference Values in Demographically Diverse Youth.

Rationale. Studies examining baseline concussion assessment scores report differences among athletes based on age,[15–21] gender,[15,19] concussion history,[16,18,19,22] and language. In addition, children with pre-existing health conditions [i.e., Attention-Deficit/Hyperactivity Disorder (ADHD) and learning disorders (LD)] report more concussion-like symptoms and perform worse on neurocognitive testing on baseline concussion assessments, compared to their counterparts who do not have these conditions.[23–27] Thus, knowledge of whether and how demographic characteristics may affect scores would support clinical interpretation of Child SCAT5 scores. Moreover, easily assessable and interpretable clinical reference values of the Child SCAT5 may assist clinicians in the management of youth with concussion. To date, limited information is available regarding the associations between Child SCAT5 scores and age, gender, health history, and socio-cultural variables, especially among middle school children. Using a large sample of middle school student-athletes, I will examine potential associations between Child SCAT5 scores and gender, age, and language spoken at home, and establish normative reference data for the Child SCAT5 among middle school age student-athletes.

Research Questions. (i) Do baseline Child SCAT5 scores differ by gender, age, or language spoken at home among middle school age student-athletes? (ii) What are the normative reference values for the middle school student-athletes on the Child SCAT5?

Study II. Interpreting Change on the Child Sport Concussion Assessment Tool, 5th Edition.

Rationale. Pre-participation concussion assessment (i.e. “baseline”) is common practice in scholastic sports. However, there is minimal research regarding how often baseline assessments should take place, particularly for middle school age student-athletes. Further, previous versions of the SCAT have learning effects[28] and low test-retest reliability.[29] These limitations may be present for the Child SCAT5. In order to better understand the clinical utility of the Child SCAT5 for post-injury evaluations, it is essential to understand the temporal stability of the instrument (i.e., the test-retest reliability). Therefore, the purpose of this study is to investigate the one-year test-retest reliability of the Child SCAT5 within a middle school age student-athlete sample, as well as explore changes in Child SCAT5 scores that may occur as a result of repeated testing.

Research Questions. (i) What is the one-year test-retest reliability of the Child SCAT5 among middle school student-athletes? (ii) What is the difference in Child SCAT5 scores from Year 1 (2017-18, herein “test” assessments) to Year 2 (2018-19, herein “retest” assessments) of baseline scores among uninjured middle school age student-athletes? (iii) What is the proportion of middle school age student-athletes who stay the same, improve, or decline in normative categories at retest compared to test? (iv) How should clinicians interpret reliable change on the Child SCAT5?

Study III. The Acute Presentation of Sports-Related Concussion Among Middle School Children During Sideline Assessment.

Rationale. The two recommended methods for interpreting Child SCAT5 performance following concussion are to (i) compare a child’s performance to his or her own personal, pre-injury baseline or, (ii) compare obtained results to normative reference values.[28] Often personal baseline preseason test results are not available, thus normative reference values can help clinicians interpret test performance and assist in concussion management. However, neither of these methods have been investigated among middle school age student-athletes. The purpose of this study is to build upon the prior two studies and examine Child SCAT5 acute sideline assessment scores in middle school age student-athletes. Specifically, this study will investigate the two methods of baseline and normative comparisons for concussed middle school age student-athletes, as well as examine the proportions of concussed student-athletes that show reliable changes on specific scores derived from the Child SCAT5.

Research Questions. (i) What are the sideline Child SCAT5 scores for middle school age student-athletes diagnosed with a concussion? (ii) How do sideline Child SCAT5 scores differ from a middle school student-athlete’s baseline assessment scores? (iii) What is the proportion of middle school age student-athletes who stay the same, improve, or worsen in Child SCAT5 normative categories on the sideline scores compared to their preseason baseline scores? (iv) What is the proportion of student-athletes that will show a reliable change in their SCAT5 scores, following injury, compared to their personal pre-injury baseline scores?

In the following chapter, I provide a literature review of concussion research with a focus on pediatric concussion assessment. In addition, this literature review identifies where knowledge gaps remain. Following an in-depth review of the literature, each study is presented as an individual manuscript, followed by a summary chapter that integrates and discusses the overall findings from this program of research.

Chapter Two: Literature Review

In this chapter I provide a comprehensive review of the literature relating to pediatric concussion. The review will begin by describing the definition, history, pathophysiology, epidemiology, and legislative action relating to sports-related concussion. Next, the literature review will examine recognition and management of concussion in the pediatric population. I will conclude with a discussion of concussion assessment, specifically the Child SCAT5.

Concussion Definition

A Sports-Related Concussion (SRC) is a "traumatic brain injury induced by biomechanical forces."[11] SRCs are commonly characterized by an immediate onset of symptoms that reflect functional disturbance to the brain. SRC can be caused by a direct impact (e.g., incidental head to head collision in American football) or indirect impact (e.g., a whip-lash mechanism). Typically, SRC results in a rapid onset of short-lived neurological impairments that often resolve spontaneously. Concussions, by definition, are not associated with macroscopic damage to the brain visible on conventional neuroimaging, such as computed tomography or magnetic resonance imaging. Concussions are best evaluated by assessments that incorporate clinical signs and symptoms. For a concussion diagnosis, the clinician must rule out other explanations for the athlete's symptoms. That is, the clinical signs and symptoms experienced by the injured athlete cannot be explained by other injuries (i.e., pre-existing vestibular dysfunctions) or comorbidities.[11]

Concussion Defined During Ancient Times

Injuries to the head and brain have been described for the past 3,000 years.[30] In ancient Greece, Hippocrates used the term "concussion" and described it as "…In cerebral concussion, whatever the cause, the patient becomes speechless…falls down immediately, loses their speech, cannot see and hear…"[31,32] Concussion was not well described or understood throughout ancient Roman, Chinese, and Indian records.[33] Between the 10th and 17th centuries, Arabic medicine described concussion as an abnormal physiological state, in contrast to a severe brain injury.[34] In early medieval medicine, we see the characterization of concussion as being caused by the brain moving in the skull and causing an injury that results in symptoms that should rapidly disappear.[35] Over time, a number of symptoms of concussion were described, such as: ringing in the ears, falling after a blow, lack of balance, "dazzling" of the eyes, "giddiness" that passes rapidly, and "slumbering" after an impact.[36]

Sport-Related Concussion in the 21st Century

In November 2001, the first international symposium on concussion in sport was held in Vienna, Austria; it was organized by the International Ice Hockey Federation (IIHF), the Federation Internationale de Football Association Medical Assessment and Research Centre (FIFA, F-MARC), and the International Olympic Committee Medical Commission (IOC).[37] This group, deemed the "Concussion in Sport Group" (CISG) provided recommendations for the assessment and management of concussions to improve athlete safety worldwide. This group provided the following formal definition of concussion: “Concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces.”[37] Further developments of this meeting involved the emphasis of neuropsychological testing for concussion evaluation and its importance in the understanding and management of a concussed athlete.[37] The CISG has reconvened every four years (Prague 2004,[38] Zurich 2008,[39] Zurich 2012,[40] and Berlin 2016[11]).

Concussion Pathophysiology and Biomechanics

Concussion pathophysiology involves an acute onset of neurological dysfunction, rather than structural damage to the brain. While concussions are characterized as a functional injury, microscopic damage in the brain can occur.[11,31,41,42] Upon suffering a concussion, multiple axons experience damage to the myelin sheath via potassium efflux and calcium influx, resulting in reduced action potentials and disrupted communication between neurons. This process is often referred to as the “neurometabolic cascade.”[11,31,41,42] Subsequently, blood supply is slightly reduced, contributing to impaired neuronal functioning. In order for the brain to re-establish homeostasis, glucose consumption increases to transfer energy to sodium-potassium (Na-K) pumps. However, glucose delivery becomes limited due to altered cerebral blood flow that increases oxidative metabolism. The influx of calcium causes axonal dysfunction within the brain. Some of these axons are unable to recover, potentially leading to the increased vulnerability of an individual suffering another concussion in the future.[41,43] This neurometabolic process is of particular concern for children because their axons are not fully developed or fully myelinated, potentially increasing the vulnerability of children to adverse effects following concussion.[44,45] Concussion researchers have used neuroimaging, fluid biomarkers, and genetic testing. However a recent systematic review[46] found that while these are important for research, further validation of such measures is needed to determine their clinical utility in the assessment of SRC. Clinical evaluation of a suspected SRC remains the accepted best practice for concussion management.[11]

Concussion has different effects on brain regions depending on the impact force, location, and host individual differences. A SRC is complex both in pathophysiology and, often times, injury biomechanics, as reflected in the variety of sports in which they occur.[11,43,47,48] According to Broglio et al[49] a concussion can be sustained by acceleration or deceleration forces transmitted to the cerebral tissue following impact to the head or elsewhere on the body. Two of the main forces that cause concussions are linear and rotational. Shear forces generated by rotational acceleration can deform the brain tissue and are considered to be the predominant mechanisms that result in concussion. However, there is no defined minimal threshold of force that results in a concussion.[49,50]

Epidemiology of Pediatric Concussion

On an annual basis, approximately 4 million children are estimated to present to emergency departments, worldwide, with SRCs or mild traumatic brain injuries sustained in daily life.[51–53] However, researchers have estimated that this likely represents approximately 12% of injuries, suggesting that closer to 33 million children sustain a concussion each year.[54]

The pediatric population, as represented in sports-related injury research, is broadly defined and encompasses a variety of samples. Such samples include high school athletes, youth athletes participating in organized recreational sports leagues, or athletes that participate in school-sponsored sports at their middle school. Injury epidemiology generally reports injury rates as number of injuries (e.g., concussions) per 1,000 or 10,000 Athletic Exposures (AE). An AE is commonly defined as a single athlete participating in a single athletic event (e.g., competitions or practices). Epidemiology operationally defines injuries, as such they may vary. One common break down of qualification of a reportable injury is one that: (i) occurred as a result of participation in an organized sports event, (ii) required medical attention by a Health Care Provider (HCP), and (iii) resulted in a restriction or suspension of the athlete's participation in the sport.[2–4,8,9,13,14]

Table 1 displays reported concussion incidence per 1,000 AE across various levels of youth sports.

Table 1. Concussion incidence per 1,000 Athletic Exposures (AE) across various youth sports, levels, and gender.

Sample	Sport	Concussion Incidence Per 1,000 AEs	Reference(s)
High School	Overall	0.24 – 0.25	Lincoln et al, 2011[10], Marar et al, 2012[5]
	Girls	0.02 – 0.13	Yard & Comstock, 2009[9], Lincoln et al, 2011[10]
	Boys	0.03 – 0.34	Yard & Comstock, 2009[9], Lincoln et al, 2011[10]
	Football	0.06 – 2.01	Marar et al, 2012[5], Lincoln et al, 2011[10], Dompier et al, 2015[7]
	Boys' Lacrosse	0.30	Lincoln et al, 2011[10]
	Boys' Soccer	0.17	Lincoln et al, 2011[10]
	Wrestling	0.17	Lincoln et al, 2011[10]
	Boys' Basketball	0.10	Lincoln et al, 2011[10]
	Baseball	0.06	Lincoln et al, 2011[10]
	Girls' Soccer	0.35	Lincoln et al, 2011[10]
	Girls' Lacrosse	0.20	Lincoln et al, 2011[10]
	Girls' Basketball	0.16	Lincoln et al, 2011[10]
	Softball	0.11	Lincoln et al, 2011[10]
	Field Hockey	0.10	Lincoln et al, 2011[10]
	Cheerleading	0.06	Lincoln et al, 2011[10]
Youth Recreational Sports	Overall	0.02	Pfister et al, 2016[4]
	Games	6.16	Kontos et al, 2013[55]
	Practices	0.24	Kontos et al, 2013[55]
	Girls	1.20	O'Kane et al, 2014
	Rugby	4.18	Pfister et al, 2016[4]
	Hockey	1.20	Pfister et al, 2016[4]
	Football	0.53 – 2.38	Pfister et al, 2016[4], Dompier et al, 2015[7]
	Lacrosse	0.24	Pfister et al, 2016[4]
	Soccer	0.23	Pfister et al, 2016[4]
	Wrestling	0.17	Pfister et al, 2016[4]
	Basketball	0.13	Pfister et al, 2016[4]
	Softball	0.10	Pfister et al, 2016[4]
	Baseball	0.06	Pfister et al, 2016[4]
	Field Hockey	0.10	Pfister et al, 2016[4]
	Cheerleading	0.07	Pfister et al, 2016[4]
	Volleyball	0.03	Pfister et al, 2016[4]

Sample	Sport	Concussion Incidence Per 1,000 AEs	Reference(s)
Middle School	Overall	0.07 – 0.75	Beachy & Rauh, 2014[8], Kerr et al, 2017[2]
	Games	1.15 – 3.73	Kerr et al, 2017[2], Kerr et al, 2019[3]
	Practices	0.63 – 1.04	Kerr et al, 2017[2], Kerr et al, 2019[3]
	Girls	0.03 – 0.61	Beachy & Rauh, 2014[8], Kerr et al, 2017[2]
	Boys	0.09 – 0.87	Beachy & Rauh, 2014[8], Kerr et al, 2017[2]
	Baseball	0.57	Kerr et al, 2017[2]
	Boys' Basketball	0.18	Kerr et al, 2017[2]
	Football	2.61	Kerr et al, 2017[2]
	Boys' Soccer	0.15	Kerr et al, 2017[2]
	Wrestling	0.51	Kerr et al, 2017[2]
	Boys' Track	0.00	Kerr et al, 2017[2]
	Girls' Basketball	0.88	Kerr et al, 2017[2]
	Cheerleading	0.68	Kerr et al, 2017[2]
	Girls' Soccer	1.30	Kerr et al, 2017[2]
	Softball	0.68	Kerr et al, 2017[2]
	Volleyball	0.34	Kerr et al, 2017[2]
	Girls' Track	0.00	Kerr et al, 2017[2]

In children below 18 years old, contact sports have the highest concussion incidence rates.[4] Specifically, rugby (4.18/1,000 AE), hockey (1.2/1,000 AE), and American football (0.53-2.38/1,000 AE) account for the highest incidence rates.[4,56] Lower concussion rates were reported for volleyball (0.03-0.34/1,000 AE), baseball (0.06-0.57/1,000 AE), and cheerleading (0.07-0.68/1,000 AE).[2,4] Middle school athletes have nearly three times the rate of concussion compared to high school athletes [0.75/1,000 AE[2] vs 0.24-0.5/1,000 AE[13,14]]. Dompier et al[7] found that youth football athletes (2.38/1,000 AE) had a slightly higher concussion incidence than other high school athletes (2.01/1,000 AE), and slightly lower incidence than college football athletes (3.74/1,000 AE). Halstead et al[56] found, from a cohort of 664 middle school football athletes, a total of 165 injuries were reported in a single school year. Concussions represented the third most common injury (n=17, 10.3%), with contusions (n=51, 30.9%) and sprains (n=32, 19.4%) representing the first and second most common, respectively.[56] When evaluating concussion epidemiology by gender, girls report a higher rate of concussion incidence than boys in sex-matched sports (e.g., soccer and basketball).[56]

Epidemiology researchers commonly study injury documentation captured by HCPs (e.g., athletic trainers) who are present in the setting of interest. Although this is a strong method of capturing injury-related information in various athletic settings (i.e., high school and college), certain other settings, such as middle schools, are often underrepresented in the literature due to the lack of an embedded onsite HCP. As such, some studies of middle school athletes rely on injury reports from coaches or parents of athletes,[57,58] which may introduce error, thus providing an inaccurate estimate of concussion incidence.[59] Further, a difficulty with middle school concussion epidemiology is the lack of well-organized injury surveillance systems in middle school and organized youth sports.[56] In addition, underreporting can happen due to fear of losing playing time or general lack of knowledge on concussion in sport.[4,60] There is a need for more research into incidence rates for the youth and middle school samples which operate differently than organized club sports.

Advancing Healthcare Initiatives for Underserved Students (ACHIEVES). Beginning in 2015, the ACHIEVES project (achieves.gmu.edu) has provided embedded athletic trainers (AT) in middle schools across Prince William County Virginia.[61] These ATs render on-site clinical care, deliver free sport safety education, and document all injuries in an electronic medical record. This project was among the first to publish studies on concussion incidence in middle school student-athletes.[2,3] During the 2015-2016 school year, there were 73 concussions across 9 middle schools in Prince William County, VA. In total, concussions occurred at a rate of 0.75/1,000 AE, with football accounting for the highest concussion rate (2.61/1,000 AE), nearly four times that of previous findings for high school and college football athletes[13,14] Overall, a higher rate of concussions occurred during girls' sports than boys' sports, and during competitions rather than practices (see

Table 1).

Concussion Legislation

Currently, all 50 states and the District of Columbia have passed laws relating to traumatic brain injury.[62] These laws tend to emphasize education relating to concussions, and preventing athletes from returning to play following a suspected concussion.[63] Washington state was the first to enact a TBI law, the Zachary Lystedt Law, in 2009.[63,64] This law required that any high school athlete suspected to have a concussion must be removed from their sporting event (e.g., practice or competition) until medically cleared to return to play by a HCP.[64] To date, the general theme to these laws is to (i) increase recognition of concussions among states, (ii) immediately remove from sport participation an athlete with suspected concussion, (iii) ensure that athletes are properly cleared to return to play following a concussion, and (iv) promote concussion education.[63] To date, researchers have not examined the possible effects of the concussion legislation on the incidence of repeat concussions or the health and welfare of injured athletes.

Virginia's Law on Sports-Related Concussions in Youth Sports. The Commonwealth of Virginia passed legislation in 2010, entitled "The Student-Athlete Protection Act."[65,66] The goals of this legislation were to ensure that student-athletes who sustain concussions are properly diagnosed, given adequate time to recover, and are comprehensively supported throughout the recovery process.[65,66] This law was amended in 2014 to include that any athlete suspected to have a concussion must be removed from play, and the athlete may not return to play for at least 24 hours.[65,67] The athlete can only be allowed to return to play once medically cleared to do so by a licensed HCP.[65,67] Also, non-interscholastic youth sports programs utilizing public school property are to create their own policies regarding how to manage concussions in accordance with the local school division's policies.[65,67] In 2016, an amendment passed that required the Board of Education to distribute guidelines for developing concussion policies, including return-to-school protocols for students with concussion.[65,68] This required each school division to develop policies and procedures regarding the identification and handling of suspected concussions among students. This law was later updated, in 2019, to include the requirement that the Virginia Board of Education collaborate with local stakeholders biennially to update the local concussion policies.[65,69] This includes educating coaches, student-athletes, and guardians of student-athletes on the risk of concussion, and the importance of immediate removal from play following a concussion or suspected concussion.[65,69]

Recognition and Early Management of Concussion

A licensed HCP should evaluate a patient showing signs and symptoms of concussion.[11] Basic management of a SRC should include removal of play to determine the athlete's state of health. If possible, the athlete should be monitored and re-assessed acutely (i.e., the next few hours) and sub-acutely (i.e., next 1-2 weeks). An athlete with a suspected concussion should not return-to-play the same day as injury.[11]

Concussion Assessment

Current assessment approaches emphasize evaluating multiple domains of functioning including commonly reported symptoms, along with testing patient's cognition and postural stability (i.e., balance). It is recommended that concussion assessment be multi-modal and be largely guided by symptom reporting.[11,70] Whenever possible, the SRC assessment should incorporate neurological, vestibular, ocular-motor, visual, neurocognitive, psychological, and cervical evaluations.[70]

Psychometric Properties of Concussion Assessment Tools

Concussion assessment tools that deploy a multi-modal method are likely to be the most appropriate in various samples of patients.[71] “Multi-modal” means that the assessment encompasses more than one component, such as symptoms, cognitive functioning (e.g., memory), and balance [e.g., Balance Error Scoring System (BESS)] that may be impaired following a concussion, and thus relevant for concussion assessment and diagnosis.[71] As shown in Table 2, multi-modal assessments, such as the Sport Concussion Assessment Tool (SCAT), have high levels of sensitivity and specificity for identifying concussed athletes. In particular, symptom evaluations are essential for concussion management.[11,70]

Table 2. Diagnostic accuracy of sideline screening assessments for suspected concussion, reported by Patricios et al[72] via a meta-analysis.

Test	Sensitivity	Specificity
Eye Tracking (e.g., King-Devick)	High	High
Multi-modal (e.g., SCAT)	High	High
Balance (e.g., BESS & mBESS)	Low	Moderate
Symptoms	Moderate	High
Cognitive	Low	Moderate
Head Impact Sensors	Low	Low

Note. SCAT = Sport Concussion Assessment Tool, BESS = Balance Error Scoring System, and mBESS = Modified Balance Error Scoring System.

Validity. Interpretation of scores on concussion assessment tools, such as the Child SCAT5, is based on the assumption that the tool can appropriately measure what it is intended to measure with minimal error. As such, reliability and validity information are needed. In concussion assessment tools, validity is often evaluated by assessing the sensitivity and specificity of a measure. In this context, sensitivity is the probability that a patient with a concussion will be correctly diagnosed (i.e., “True-Positive”). Specificity refers to the probability that a patient will be correctly classified as not having a concussion (i.e., “True-Negative”). Receiver Operating Characteristic (ROC) Curves that generate Area Under the Curve (AUC) values are commonly utilized to understand the diagnostic/classification accuracy of an instrument. If the AUC values are 0.50 this is indicative of a 50% likelihood of correctly classifying a patient as having a given disease or condition that the tool tests for (i.e., a flip of a coin). If the AUC values are close to the value of 1.00, this would be indicative of a strong classification accuracy of the condition. These values can then be used to generate score cutoffs with corresponding estimates of sensitivity and specificity.[72]

Table 3 reports the sensitivity and specificity for various concussion assessment tools, including components that are made up in prior versions of the Child SCAT5 (e.g., SCAT2, SCAT3, SAC, etc.).

Table 3. Sensitivity and specificity of individual assessment measures and multimodal concussion assessment instruments.

Assessment	Sensitivity (%)	Specificity (%)	Reference
SCAT2 total symptoms	84.4	100.0	Putukian et al, 2015[73]
SCAT2 symptom severity	80.0	100.0	Putukian et al, 2015[73]
SAC	94.0	76.5	Barr and McCrea, 2001[74]
	95.2	76.4	McCrea, 2001[75]
	79.1	----	McCrea et al, 2002[76]
	79.8	91.1	McCrea et al, 2005[77]
	53.8	----	Echlin et al, 2010[78]
	55.6	----	Marinides et al, 2015[79]
	20.0	82.4	Galetta et al, 2016[80]
	40.6	90.9	Putukian et al, 2015[73]
BESS	36.0	94.6	McCrea et al, 2005[77]
	80.0	----	Echlin et al, 2010[78]
	80.0	----	Marinides et al, 2015[79]
mBESS	25.0	100.0	Putukian et al, 2015[73]
SCAT2	100.0	----	Galetta et al, 2013[81]
	78.10	95.70	Putukian et al, 2015[73]
BESS, SAC, & King-Devick Test	100.0	----	Marinides et al, 2015[79]
Pitchside Concussion Assessment Tool	84.6	74.0	Fuller et al, 2014[82]
SCAT2 & King-Devick Test	100.0	----	Galetta et al, 2013[81]
Graded Symptom Checklist, BESS, & SAC	94.7	89.1	McCrea et al, 2005[77]

Note. SCAT = Sport Concussion Assessment Tool, BESS = Balance Error Scoring System, mBESS = Modified Balance Error Scoring System, and SAC = Standard Assessment of Concussion.

Reliability. Reliability of concussion assessment tools is commonly appraised with test-retest reliability analyses. Test-retest reliability is evaluated by having participants undergo two assessments with the tool at two different time points. Test-retest reliability is an estimate of the temporal stability and consistency of test scores. Correlation coefficients [Pearson (r_p) and Spearman (r_s)] are used to measure the test-retest reliability and can be interpreted using existing guidelines (i.e., ≥.90=very high; .80-.89=high; .70-.79=adequate; .60-.69=marginal; <.60=low).[83,84] To date, the temporal stabilities of sideline concussion assessment is limited in children,[85] and no research has investigated the temporal stability of the Child SCAT5. Test-Retest reliability coefficients for SCAT components are reported in

Table 4.

Table 4. Test-retest reliability coefficients of SCAT3 and Child SCAT3 components.

SCAT component	Sample	Assessment Interval	Reliability Coefficient	Resource
Total Symptoms	Professional Ice Hockey Athletes	367.0 ± 24.2 days	r_s=.41	Hänninen et al, 2017[29]
Symptom Severity	Professional Ice Hockey Athletes	367.0 ± 24.2 days	r_s=.38	Hänninen et al, 2017[29]
	Youth football & Youth Soccer	64.3 ± 62.9 days	r_p=.77	Nelson et al, 2017[85]
SAC	Professional Ice Hockey Athletes	367.0 ± 24.2 days	r_s=.34	Hänninen et al, 2017[29]
	High School Athletes	57.9 ± 4.2 days	r_p=.49	Valovich-McLeod et al, 2006[86]
	High School & Collegiate Athletes	7 days & 196 days	r_s=.41 & r_s=.45	Chin et al, 2016[87]
SAC-C	Youth football & Youth Soccer	64.3 ± 62.9 days	r_p=.50	Nelson et al, 2017[85]
Immediate Memory	Professional Ice Hockey Athletes	367.0 ± 24.2 days	r_s=.25	Hänninen et al, 2017[29]
Concentration	Professional Ice Hockey Athletes	367.0 ± 24.2 days	r_s=.46	Hänninen et al, 2017[29]
Delayed Recall	Professional Ice Hockey Athletes	367.0 ± 24.2 days	r_s=.33	Hänninen et al, 2017[29]
mBESS	Professional Ice Hockey Athletes	367.0 ± 24.2 days	r_s=.25	Hänninen et al, 2017[29]
	Youth football & Youth Soccer	64.3 ± 62.9 days	r_p=.02	Nelson et al, 2017[85]
	High School & Collegiate Athletes	7 days & 196 days	r_s=.50 & r_s=.52	Chin et al, 2016[87]
BESS	High School Athletes	57.9 ± 4.2 days	r_p=.68	Valovich-McLeod et al, 2006[86]

Note. SCAT = Sport Concussion Assessment Tool, BESS = Balance Error Scoring System, SAC = Standard Assessment of Concussion, SAC-C = Standard Assessment of Concussion – Child Version, mBESS = Modified Balance Error Scoring System, r_p = Pearson correlation coefficient, and r_s = Spearman correlation coefficient.

Reliable Change Estimates. Serial administration of concussion assessments is common practice among clinicians. Serial assessment can include repeated baseline measures, and follow up post-injury measures. The American Academy of Clinical Neuropsychology recommends the use of serial assessments to aid in differential diagnoses, tracking psychometric strengths and weaknesses over time, and managing neurological and psychiatric conditions.[88] However, appropriately appraising how scores may change following injury can be challenging. Specifically, it is important to determine how much change on an assessment is due to a patient's condition versus other factors. Jacobson and Truax[89] first proposed a psychometric method for determining how much change could be deemed "reliable" upon serial administration. Specifically, this method involved calculating a Reliable Change Index (RCI), which is expressed as a *z*-score and is interpreted with corresponding confidence intervals (CI).[89] This method has since been revised through psychometric research.[90] Reliable change estimates that are based on calculating change scores (e.g., second assessment scores minus first assessment scores) to generate standard error of the difference scores (S_{diff}) that can then be used to create CIs (commonly 80% CI, 90% CI, and 95%) are recommended by Iverson et al.[91] These CIs then provide a range of cutoff scores that would be deemed reliable changes. Prior concussion studies have used this methodology.[91,92]

Another method for examining reliable change is to establish cutoff scores based on the natural distribution of test-retest difference scores in uninjured athletes. This has previously been done by Hänninen et al[93] with the SCAT3 for professional ice hockey athletes. Specifically, these researchers identified the 10th percentile cutoff as an estimate of “uncommon” difference scores, and the 5th percentile as an estimate of “extremely uncommon” difference scores. Currently neither method, reliable change estimates or natural distribution of change scores percentile cutoffs, have been investigated for the Child SCAT5. As such, there are no evidence driven cutoffs for what could be considered a statically reliable and clinically meaningful change in Child SCAT5 scores.

Sport Concussion Assessment Tool (SCAT)

The SCAT is a multi-modal, standardized assessment tool for HCPs to evaluate patients with a suspected SRC. The SCAT was developed in 2004, during the 2nd International Conference on Concussion in Sport in Prague, Czech Republic, with the intent to standardize clinician concussion assessment.[38] Experts in the field created the SCAT by combining existing assessment tests [e.g., Standard Assessment of Concussion (SAC) and Post-Concussion Symptom Scale (PCSS)] into a single battery. However, it was not designed to assess concussion in pediatric athletes.[38] The SCAT, second edition (SCAT2) was created during the 3rd International Conference on Concussion in Sport in 2008[39] but was limited to athletes ≥10 years of age. It was not until the 4th International Consensus Conference in 2012 that a separate, standardized concussion assessment for children ages 5-12, the Child SCAT, third edition (Child SCAT3), was created.[40] The Child SCAT3 incorporated similar domains as the adult version [i.e., the SCAT, third edition (SCAT3)] but also incorporated several developmental adaptations for use with pediatric athletes.[4] Most recently, the Child SCAT5 was developed during the 5th International Conference on Concussion in Sport in 2016.[11] The timeline of the development of each version of the SCAT since the first CISG consensus is summarized in Table 5.

Table 5. SCAT iterations and respective years of development, age ranges, and CISG meeting.

Year	Tool	Age Range	CISG Meeting
2004	SCAT	Not specified	2nd International Conference on Concussion in Sport[38]
2008	SCAT2	10+	3rd International Conference on Concussion in Sport[39]
2012	SCAT3	13+	4th International Conference on Concussion in Sport[40]
	Child SCAT3	5-12	
2016	SCAT5	13+	5th International Conference on Concussion in Sport[11]
	Child SCAT5	5-12	

Note. SCAT = Sport Concussion Assessment Tool; SCAT2 = Sport Concussion Assessment Tool 2nd Edition; SCAT3 = Sport Concussion Assessment Tool 3rd Edition, SCAT5 = Sport Concussion Assessment Tool 5th Edition, CISG = Concussion in Sport Group.

Child Sport Concussion Assessment Tool 5th Edition (Child SCAT5)

The Child SCAT5 is a multi-modal standardized concussion tool designed for medical professionals to conduct pre-injury (i.e., "baseline") and post-injury assessments of SRC in children ages 5-12. Davis and colleagues[12] described the Child SCAT5 as retaining the key components of its predecessor, the Child SCAT3, but with improved feasibility for assessment of children and better methods for capturing cognitive/balance data. Specifically, the Child SCAT5 refined administration instructions and methods for assessing cognition (e.g., the option to re-attempt digits backwards) and balance (e.g., the addition of a single-leg stance). Further, the Child SCAT5 includes a concussion symptom questionnaire, cognitive tests, and a balance examination. Specific details about each of the Child SCAT5 components are provided in sections below. Briefly, in terms of specific tests and scores, the Child SCAT5 includes the following: total number of symptoms endorsed by the child (range: 0-21); severity of symptoms reported by the child (range: 0-63); the Standard Assessment of Concussion – Child Version (SAC-C, range 0-26) immediate memory (range: 0-15), concentration [sum of digits backwards (0-5) and days of the week in reverse order (0-1); range: 0-6], and delayed recall scores (0-5); and the Modified Balance Error Scoring System (mBESS) total sum of errors during double, single, and tandem leg stances (range: 0-30). Higher scores on cognitive measures (e.g., immediate memory, concentration, delayed recall) indicate better functioning and higher scores on symptom reporting and balance errors indicate worse functioning.

Immediate or On-Field Assessment

For appropriate clinical diagnosis of a concussion, a plausible injury mechanism must occur. On the Child SCAT5, clinicians, such as ATs, who are on the sideline of a sporting event can document the observed mechanism of head impact and subsequent patient behavior. The specific observable signs as noted on the Child SCAT5 are: (i) lying motionless on the playing surface; (ii) balance/ gait difficulties/ motor coordination: stumbling, slow/ labored movements; (iii) disorientation or confusion, an inability to respond appropriately to questions; (iv) blank or vacant look; and (v) facial injury after head trauma (see Appendix B). Combining detail of injury mechanisms and observable signs will enhance both the sensitivity and specificity of the clinical evaluation.[95]

The design of the Child SCAT5 allows clinicians to immediately assess a patient after a suspected injury on the field or sideline. The Child SCAT5 incorporates a list of "Red Flags" that includes the following: neck pain or tenderness, double vision, weakness/tingling/burning in arms or legs, severe or increasing headache, seizure or convulsion, loss of consciousness, deteriorating conscious state, vomiting, and increasingly restless, agitated, or combative. These red flags may reflect a more severe and potentially life-threatening injury and, if observed in the patient, the clinician should activate the appropriate emergency medical response.

The Glasgow Coma Scale (GCS) is used to assess unconsciousness.[96] The GCS is made up of three subcomponents: Best Eye Response (score: 1-4), Best Verbal Response (1-5), and Best Motor Response (1-6). For a patient to receive a score of anything less than 15, warrants an emergency medical concern and care should be rendered immediately.[96,97] To date, no study has examined the utility of the GCS in the Child SCAT5. The GCS has consistently been incorporated in each of the SCAT and Child SCAT editions, however it is intended to be used as a reminder to medical personnel to assess patients for a more severe, even life-threatening, brain injury.[28]

Lastly, the Child SCAT5 Immediate or On-Field Assessment section incorporates a cervical spine evaluation made up of three yes/no questions. These questions require the clinician to evaluate if the patient has any reported cervical (neck) pain, restricted cervical range of motion, bilateral limb strength, and bilateral limb sensation. Poor cervical function may indicate a serious cervical injury or potentially a life-threatening emergency.

Office or Off-Field Assessment

Once the emergent concerns are assessed, the second portion of the Child SCAT5, the Office or Off-Field Assessment, is completed. This section includes: athlete background (e.g., demographic information, and medical history), symptom evaluation, cognitive screening, neurological screening, delayed recall, and a clinical diagnosis decision.

Athlete Background. The first component of the Off-Field Assessment on the Child SCAT5 includes capturing demographic characteristics (e.g., athlete's name, sport/team/school, years of education completed, age, gender and dominant hand). Further, the Child SCAT5 is comprised of a medical history portion that enables the child to self-report if the child has ever been: hospitalized for a head injury; diagnosed/treated for headache disorder or migraines; diagnosed with a learning disability/dyslexia; diagnosed with ADHD; diagnosed with depression, anxiety or other psychiatric disorder; and their current medication use.

Demographic characteristics and medical histories are important because some of them are associated with performance on concussion assessments. For example, athletes with ADHD report more concussion-like symptoms and greater severity of concussion-like symptoms than athletes without ADHD.[98] Further, athletes with ADHD perform modestly worse on objective components of concussion evaluations [e.g., BESS and standard assessment of concussion (SAC) scores].[27,99,100] Athletes with learning disorders also report more symptoms and perform a slightly worse on the SAC than athletes without learning disorders on baseline assessments.[87] Athletes with a self-reported personal history of depression and anxiety endorse greater baseline symptom scores.[101] Distinguishing between concussion symptoms and pre-existing health conditions can be difficult, but all of these conditions are important to consider when interpreting SCAT performances both before and after injury.

Symptoms. Symptom assessment plays a vital role in the evaluation and management of concussions. The SCAT3 and SCAT5 use a modified version of the original PCSS which contains 22 items, and this scale is commonly used for assessing concussion symptoms.[102] The PCSS has established clinical utility for the assessment of concussion and monitoring concussion recovery.[103] Iverson et al[104] compared the most commonly reported symptoms among high school boys and girls during preseason, baseline assessments using the Post Concussion Scale, as measured on Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT®). Among boys (n=18,290), the most common symptoms were fatigue (20.8%), sleeping less than usual (20.3%), trouble falling asleep (18.4%), difficulty concentrating (17.5%), and headache (16.2%). For girls (n=15,442), the most common symptoms were fatigue (26.8%), sleeping less than usual (25.5%) trouble falling asleep (23%), headache (24.6%), sadness (22.6%), feeling more emotional (21.9%), and difficulty concentrating (21%). Further research by Iverson and Lange[105] showed that "post-concussion-like" symptoms are also experienced among healthy individuals, indicating that "concussion" symptoms are not necessarily unique to a concussed patient, and are experienced by many individuals in the absence of head trauma.[105] Further, regarding post-concussion symptoms, Kerr et al[106] reported the top three symptoms in youth, high school, and college football athletes (n=3,000+) are headache, dizziness, and difficulty concentrating.[106] When comparing age groups, there does not appear to be significant differences between youth and college athletes in terms of acute symptom reporting.[106] Of note, acute post-concussion "dizziness" has been predictive of protracted recovery (i.e., ≥ 21 days) in high school football players.[107] Further, a recent systematic review reported that greater symptom severity endorsement acutely and sub-acutely following a concussion are the strongest predictors of slower recovery.[108]

The symptom component of the Child SCAT5 is a 21-item adaptation of the original 62-item Health and Behavior Inventory (HBI),[109,110] which has previously established group differences among concussed and uninjured children.[109] The HBI has not undergone any concurrent validation against the PCSS as incorporated on the SCAT3 and SCAT5. The symptom evaluation component of the Child SCAT5 is often viewed as the most important component of the tool.[111] The Child SCAT5 is different from the SCAT5 in that it incorporates both child and parent report symptom questionnaires. The Child SCAT5 frames symptoms in the first person to assist children with comprehending the item. For example, when assessing if the athlete has a headache, the Child SCAT5 enables the athlete to rate their headache with the phrasing "I have a headache," whereas a headache is phrased solely as "headache" in the SCAT5. There are 21 self-reported symptoms rated on a 3-Point Likert-type scale: 0 = "Not at all/ Never," 1 = "A little/Rarely," 2 = "Somewhat/Sometimes," and 3 = "A lot/Often." This creates a maximum total symptom severity score of 63, in which a higher score is indicative of a greater symptom burden. The symptom questionnaire is intended to systematically measure the number of individual symptoms and the overall symptom severity.[112] The Child SCAT5 also includes two dichotomous components assessing if the symptoms get worse with physical or mental activity, followed by a scale of 0-10 assessing how children feel overall (0 = very bad, and 10 = very good).[12]

Across prior research, younger children have reported a greater number of total symptoms and greater symptom severity compared to older children,[28] and girls tend to report more symptoms than boys.[28] The PCSS has been used in the children and adolescents and it did not differentiate well between injured and uninjured children.[113] At present, it remains unknown if the HBI is more or less useful for acute concussion assessment in children compared to the PCSS.[28,113] Table 6 summarizes the average pre-injury baseline SCAT total symptoms and symptom severity ratings among various pediatric samples.

Table 6. Total symptoms and symptom severity (M±SD) reported among pediatric samples.

Sample	Tool	Age (years)	n	Symptoms	Symptom Severity	Reference
Youth Sports	Child SCAT3	5-13	234 girls 241 boys	8.4±5.3 9.9±5.1	11.9±9.2 15.1±9.8	Brooks et al, 2017[15]
Youth Football & Soccer	Child SCAT3	5-13	55 girls 55 boys	Not reported	10.8±8.4 10.9±7.9	Nelson et al, 2017[17]
Youth Ice Hockey	Child SCAT3	7-12	227 boys	7.9±5.1	11.4±8.4	Porter et al, 2015[20]
Middle School & High School	SCAT2	12-16	166 girls 195 boys	2.9±3.8 2.2±3.9	20.0±2.2 20.6±2.0	Glaviano et al, 2015[21]

Note. SCAT = Sport Concussion Assessment Tool; SCAT2 = Sport Concussion Assessment Tool 2nd Edition; SCAT3 = Sport Concussion Assessment Tool 3rd Edition

Cognition

Cognition is commonly evaluated in concussion assessments in the form of concentration, memory, and critical processing tasks.[12] Concussion is a highly individualized injury, as such, athletes will vary in how they present cognitively following injury.[92] Cognition remains a complicated clinical assessment to incorporate in evaluations and recovery tracking for patients. This is, in part, due to evidence of ceiling and practice effects on the SAC/SCAT.[115] However, Babl et al[116] found that children with a concussion diagnosis scored significantly lower on cognitive assessments than a control group. Further, prior research on sideline cognitive assessments revealed that the SAC is sensitive to concussion in high school[87,117] and collegiate[87] athletes, but the sensitivity of the SAC declines over the first 24 hours following injury and by 48 hours most athletes appear to score in the broadly normal range on the test.[118] This is due to natural recovery and the crudeness of the measure. Few studies have tested the cognitive abilities of athletes after a full clinical recovery following a concussion. Kriz et al[119] used ImPACT® baseline and return-to-play scores from 13-18 year old ice hockey players, and found that 28.1% (9/32) of the athletes had impaired scores on the test even though they were thought to have a full recovery.[119] Further research has indicated that stress may impact cognitive functioning.[120] Therefore, baseline and/or post-injury test scores could be affected by factors other than concussion. Broglio and colleagues[121] found that some neurocognitive decrements can be present when an athlete is asymptomatic from a concussion. Not many studies have examined cognitive test performance on concussion assessments among middle school students. Therefore, it is unknown if these issues are prevalent in this population.

Standardized Assessment of Concussion – Child Version (SAC-C). The cognitive screening component of the Child SCAT5 incorporates several tasks including: immediate memory, digits backwards, days in reverse order, concentration, and delayed recall. Immediate memory is tested as three sets of five trials, during which the clinician reads aloud a list of five words to the patient, and the patient is asked to repeat the five words back to the clinician. A point is earned for each correct word repeated per trial (for a total of 5 possible points per trial) and a sum of the three trials is calculated (for a total of 15 possible points overall). For digits backwards, the clinician reads a list of numbers aloud, and the patient is to repeat the list back to the clinician, in reverse order. Research has shown that the digits backwards component of the Child SCAT3 is difficult for children to complete with or without a concussion.[115,122] As such, children are granted two chances to correctly verbalize the string of numbers and are scored out of 5 on the

Child SCAT5. Prior findings on the SCAT2 indicated that children had trouble reporting months of the year in reverse order,[115,122] and as such, the Child SCAT5 incorporates days of the week.[12] Days in reverse order is a correct or incorrect score (i.e., 0 or 1 point) for correctly verbalizing the days of the week in reverse order. Concentration is a total score calculated as the sum of digits backwards and days in reverse order (for a total of 6 possible points). As an evaluation of memory, the delayed recall test assesses the athlete's ability to retain the words listed during the immediate memory component of the Child SCAT5 and must be assessed after at least 5 minutes have elapsed since the completion of the immediate memory assessment.

The SAC-C is a version of the original SAC but specific to children. The original SAC is a validated measure for assessing cognitive function and acute deficits that are associated with concussion.[74,123,124] However the sensitivity and specificity of this measure vary, as noted in Table 3. Further, the SAC-C has established clinical utility as a diagnostic component of the Child SCAT3 in children.[116] Traditionally, the SAC total score is calculated as the sum of scores including: orientation, concentration, immediate memory, and delayed recall.[123] Barr and McCrea[74] investigated the validity of the SAC in a cohort of high school and collegiate athletes across 60 and 120 days. They concluded that the SAC had 94% sensitivity and 76% specificity. Overall, the findings indicated that the SAC is a valid instrument for assessing the acute effects of SRC.[74] However, Dessy et al[125] concluded that while the SAC does demonstrate a high sensitivity and specificity, it cannot be used for monitoring recovery due to a quick return to baseline scores within the first 48 hours after concussion. It should be noted that the SAC and SAC-C are not intended to be a substitute for a comprehensive neuropsychological evaluation, rather they should be used as sideline screening measures or acute measures during the first 24-36 hours following injury, to assist in clinical decision making for a suspected concussion.

Normative reference values for the SAC and SAC-C have been published.[15,17,20,21,27,126,127] Nelson et al[17] found older children (ages 12-13) perform better on the SAC-C than younger children (ages 5-7) at baseline. Schnieder et al[128] found girls perform better on digits backwards than boys. In addition, our prior findings in a nested case-control study indicated that children with ADHD will perform similarly to healthy controls (i.e., children without ADHD or other pre-existing health conditions) at baseline on the SAC-C via the Child SCAT5.[129] Of note, the SAC-C as included on the Child SCAT3 does include a measure of orientation. This measure was removed from the Child SCAT5, due to "doubtful usefulness in young children."[12] As such, current normative data on the SAC-C as measured on the Child SCAT3, no longer represents what could be considered "typical" or "normal" scores for patients as the maximum score is now 4 points (26 points total) lower than the prior version of the measure (30 points total). To date, no normative values have been published on the SAC-C as assessed on the Child SCAT5. Previously reported normative reference values for cognitive scores are provided in

Table 7.

Table 7. Cognitive scores (M±SD) reported among pediatric samples.

Sample	Tool	Age (years)	n	SAC/ SAC-C*	IM	Con	DR	Reference
Youth Sports	Child SCAT3	5-13	234 girls 241 boys	24.9±3.5 23.9±3.9	13.7±1.7 13.2±2.0	4.1±1.3 3.8±1.3	3.6±1.3 3.7±1.3	Brooks et al, 2017[15]
Youth Football & Soccer	Child SCAT3	5-13	55 girls 55 boys	25.3±2.6 25.1±3.1	13.7±1.4 13.6±1.6	3.80±1.01 3.98±1.07	4.1±1.0 4.0±1.3	Nelson et al, 2017[17]
Youth Ice Hockey	Child SCAT3	7-12	227 boys	24.4±3.5	12.9±2.3	3.8±0.1	3.9±1.2	Porter et al, 2015[20]
Middle School & High School	SCAT2	12-16	166 girls 195 boys	26.9±2.0 26.6±2.2	14.6±0.9 14.3±1.0	3.6±1.1 3.7±1.2	4.0±1.0 4.2±1.0	Glaviano et al, 2015[21]

Note. SCAT = Sport Concussion Assessment Tool; SCAT2 = Sport Concussion Assessment Tool 2nd Edition; SCAT3 = Sport Concussion Assessment Tool 3rd Edition, SAC = Standard Assessment of Concussion, SAC-C = Standard Assessment of Concussion – Child Version, IM = Immediate Memory, Con = Concentration, DR = Delayed Recall.
*The SAC/SAC-C scores incorporate orientation measures (total score range: 0-30).

Balance

The balance error scoring system (BESS) is commonly used among both clinicians and researchers to assess postural stability in patients, and a modified version is a component of the Child SCAT5.[12,130] The BESS is scored by a clinician/researcher observing a patient in three stances (double, single, and tandem leg stances) on both hard and foam surfaces, and counting for each imbalance-related error committed by the patient.[131] Khanna et al[132] used BESS to identify if there are differences in balance based on age, gender, sport, height, weight, or body mass index. There were no differences found between any of the variables except for gender. Specifically, girls were significantly better on a foam surface than boys and only within the 10-13 year age group.[132] Further, Bell et al[131] published a systematic review on the BESS showing good intra- and interrater reliability.[131] Echemendia et al[28] reported that the BESS appeared to have moderate validity, reliability, and practicality for assessing motor/balance deficits for acute SRC evaluation. Most of the research regarding the BESS, has examined high school or collegiate athletes.[133] There is minimal research for the BESS, or the modified version (more detail on the modified version below), among children (ages <14 years).

The Modified Balance Error Scoring System (mBESS). The mBESS is a measure used in the clinical evaluation of static balance and postural stability. The mBESS incorporates the same assessment components as the BESS, with the exception of the foam surface component. The mBESS is often incorporated in sideline assessment of a concussion due to the simplicity and brevity of completing the test.[28,134] The mBESS is made up of three stances: double leg (i.e., standing straight with feet together), tandem stance (i.e., standing with the dominant foot placed directly in front of the non-dominant foot), and single leg stance (i.e., standing only on the non-dominant foot, with dominant foot suspended). Each position is performed for 20 seconds per trial on a hard surface (e.g., gym floors). Participants keep their eyes closed and hands on their hips throughout each trial. Scores on the mBESS are calculated by assessing for errors when completing each trial. An error is any time the participant demonstrates a loss of balance (e.g., takes hands off hips, bends forward, or steps out of stance). The maximum errors that can be counted per trial is 10, and the maximum mBESS total score is 30. A low total score for the mBESS indicates a good performance, and a high score indicates poor performance.

The mBESS on the Child SCAT5 incorporates the three stances (double leg, tandem stance, and single leg stances). The mBESS on the Child SCAT3 incorporates the same components with the exception of single leg stance. Currently, literature remains mixed on the utility of the mBESS for discriminating concussed and non-concussed children.[28] Putukian et al[101]reported that concussed collegiate athletes had significantly more errors on the mBESS than controls. In addition, when scores were examined as acute assessments, or acute assessments versus baseline comparisons, both were able to distinguish between concussed and non-concussed athletes.[87] However, this finding has not been replicated in pediatric samples. The research on pediatric samples suggests that the mBESS is vulnerable to practice effects if athletes are retested within a few days.[133] To date, no normative values have been published on mBESS testing as assessed on the Child SCAT5. Normative data have been produced for the mBESS portion of the Child SCAT3. Differences on the mBESS have been reported by age,[15,17] and gender.[15,17]

Further, there is evidence to suggest that children with ADHD will perform somewhat worse compared to healthy controls on the mBESS at baseline.[129] In general, athletes are able to complete baseline mBESS testing without errors for the double leg stance.[22,135] Single leg stance has consistently shown to have the highest error scores of the mBESS.[22,135] Regarding interrater reliability of the mBESS, double leg stance, tandem stance, and single leg stance have high, moderate, and low reliability, respectively.[101] A comprehensive evaluation of the mBESS from baseline measures of pediatric athletes has not been conducted. Such a study could provide normative data that may not only fill the gap in the literature, but also assist clinicians in the management of concussed pediatric athletes.

Table 8 displays the average reported error scores for the mBESS in pediatric athletes.

Table 8. MBESS scores (M±SD) reported among pediatric samples.

Sample	Tool	Age (years)	n	mBESS*	Reference
Youth Sports	Child SCAT3	5-13	234 girls 241 boys	0.7±1.0 1.2±1.5	Brooks et al, 2017[15]
Youth Football & Soccer	Child SCAT3	5-13	55 girls 55 boys	1.3±2.0 4.2±3.2	Nelson et al, 2017[17]
Youth Ice Hockey	Child SCAT3	7-12	227 boys	1.6±2.2	Porter et al, 2015[20]

Note. SCAT = Sport Concussion Assessment Tool; SCAT2 = Sport Concussion Assessment Tool 2nd Edition; SCAT3 = Sport Concussion Assessment Tool 3rd Edition;
*mBESS as collected by Brooks et al[15] and Porter et al[20] represent scores that are only made up of double leg and tandem leg stances, whereas Nelson et al[17] represent mBESS scores made up of double leg, tandem leg, and single leg stances.

Sport Concussion Assessment Tools and Clinical Diagnosis of Concussion

Combining independent components of the SCAT3 results in higher sensitivity and specificity values than a single component.[71,124,136] This lends further support for the multi-modal assessment of concussion to evaluate function across multiple domains.[115] There are two general approaches to concussion assessment interpretation for clinical practice. The first approach involves evaluating an athlete based upon their own pre- and post- injury performance scores. That is, identifying changes from a pre-injury baseline assessment on a day-of-injury assessment, and using that information to assist with diagnosing the suspected concussion. In contrast, the second approach involves comparing the athletes' day-of-injury evaluation results to published normative data. The latter approach may be more conducive to large athletic samples in which assessing baselines for large numbers of athletes is resource intensive and not feasible. In addition, multiple studies have identified that the sensitivity and specificity of the normative approach to assessment is nearly identical to the individual baseline comparison.[71,93,124] Currently, there is a gap in the literature to evaluate these approaches in children.

Baseline (Pre-Injury) and Post-Injury Comparisons. Baseline concussion assessments are intended to be used as a pre-season evaluation conducted by a HCP to assess pre-injury symptoms, cognition, and balance. Baseline testing commonly takes place during pre-season/pre-participation physical evaluations.[11] Multiple tools exist that can be used as both a baseline collection and post-injury assessment (e.g., ImPACT®, XLNT Brain, King-Devick, and Child SCAT5). If baseline testing is utilized in a clinical setting, research suggests that baseline testing (either computerized or paper-and-pencil) should be conducted every 1-2 years.[11,137] Baseline concussion testing may be particularly helpful for those who have pre-existing health conditions (e.g., ADHD, learning disabilities, anxiety, etc.).[11]

There is very little research, to date, examining baseline preseason test results in comparison to post-injury test scores in children. With our current access to the middle schools via the ACHIEVES project, we have the opportunity to investigate pre- and post-concussion Child SCAT5 performance in this underrepresented population. Further, we can also investigate test-retest reliability of the Child SCAT5. This is important because the Centers for Disease control and Prevention (CDC)[138] and the CISG[1] have called for clinicians to utilize reliable and valid testing instruments for concussion management in pediatrics.

There are published studies comparing baseline to post-injury scores for the SCAT2 and SCAT3.[73,93] Concussed athletes report significantly greater PCSS scores than controls up to eight days after concussion.[87] SAC scores were significantly lower within 24 hours post-injury but not 8 days following injury.[87] Throughout early stages of concussion recovery, some studies have shown that there are no statistically significant differences on SCAT/ SCAT2 total scores or SAC scores within 3-5 days post-injury.[118,124,139,140] BESS and mBESS scores are worse shortly after a concussion, but normalize quickly in the following days.[87,101] Putukian et al[101] investigated the utility of the SCAT2 in collegiate athletes with SRC and found that when concussed patients were compared to their baselines there was a 3.5-point drop in the total SCAT2 score.

Individual baseline comparisons to post-injury scores may be misleading for clinical interpretation if patients endorse a high number and severity of symptoms at baseline.[93] Further, baseline scores can exhibit considerable individual score variations unrelated to concussions, such as in association with demographic characteristics,[15,19] health history,[141–145] and daily activities, such as exercise.[146] As such, acute baseline to post-injury concussion assessment comparisons should be interpreted cautiously. There is no research currently to investigate the pre- to post-injury scores of the Child SCAT5 among concussed children. Such research could inform acute clinical management of this injury within the pediatric population.

Normative Data. Normative data is intended to establish classification ranges of scores for various concussion assessment tools and can be stratified by various demographic variables. Normative reference values can vary by age, gender, and other personal or demographic characteristics (e.g., athletes with pre-existing health conditions or low socio-economic status).[11,137] Therefore, norms are maximally useful if the individual person's test scores, following injury, are compared to a normative sample that is similar on these relevant characteristics. Hänninen et al[93] found that using normative values for interpreting post-injury scores from professional ice hockey players, on the SCAT3, was as useful as comparing their scores to their own personal baseline scores. As such, normative measures may be a more feasible option for HCPs to deploy in athletic settings.[93] In addition, the CISG suggests that using normative data may lead to more conservative post-injury management.[115,147] In the present literature, normative ranges have been published for adults for the SCAT2 and SCAT3[126,127,148] and in pediatric samples for the Child SCAT3, SCAT3, and SCAT2.[15,17,18,20,21,149] However, to date, normative values of the Child SCAT5 have not been published.

Proper interpretation of the Child SCAT5 following a suspected concussion requires an understanding of whether and how demographic variables might influence, or be associated with, performance in pediatric athletes. Previous studies have shown differences on various concussion-related tests among athletes of different ages,[15,19] genders,[15,19] concussion histories,[16,18,19,22] pre-existing medical conditions,[141–145] races,[150] and native language.[151] A majority of these studies examined adolescents and adults, while research targeting the children is limited. Further, normative reference values for prior iterations of the Child SCAT5 have not stratified values by gender, age, or language differences, despite evidence that these variables might be associated with baseline performance. When athletes perform very well or particularly poorly during their baseline preseason evaluations, comparing and interpreting their post-injury scores to normative reference values can be challenging.[152,153] Moreover, using normative reference values to interpret post-injury scores in youth who have pre-existing conditions might be less useful and less accurate if those pre-existing conditions are associated with greater symptoms or worse performance on the measures.[115]

Limitations of the Child SCAT5

As previously mentioned, there is currently no reliability and validity research on the Child SCAT5. Although reliability and validity have been assessed for measures that are incorporated on the Child SCAT5 (e.g., mBESS), the overall reliability of the tool has not been investigated. Utilizing the SCAT3, Hänninen et al[29] reported low one-year test-retest reliability, and encouraged caution when interpreting scores from baseline to post-injury in adult athletes. There are components of the Child SCAT5 that involve a rater's interpretation of performance and scoring (i.e., mBESS); this can present a limitation if the rater is not well trained. In addition, the Child SCAT5 is written in English, presenting a limitation to non-native English-speaking patients. The testing environment can also impact performance on the Child SCAT5. Conditions such as loud spaces, outdoors, or surfaces that are not flat could affect the participants' focus and performance on the test. Further, there is evidence to suggest that quality of sleep, stress, exercise, and fatigue can impact participants' performance on concussion assessment tools,[154,155] although this has not been investigated specifically on the Child SCAT5. Moreover, learning and ceiling effects have been reported in some components of the SCAT and Child SCAT3.[28] Such effects can make it difficult to interpret changes between baseline and post-injury scores.[28] The screening component of the Child SCAT5 includes self-reported health history, which can be limiting if children are unaware or unsure of their health history. Wojtowicz et al[156] investigated the consistency of self-reported concussion history in adolescent athletes and found that, overall, student-athletes were capable of consistently reporting their concussion history. This was found in a sample of high school athletes, and may or may not hold true for middle school students.

Chapter Three: Study I - Child Sport Concussion Assessment Tool 5th Edition: Normative Reference Values in Demographically Diverse Youth

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Abstract

Objectives: The Child Sport Concussion Assessment Tool 5th Edition (Child SCAT5) is designed for pediatric concussion management. Understanding associations between Child SCAT5 scores and demographic characteristics can aid clinical decision making. This study examined sociodemographic differences (gender, age, and language spoken at home) on baseline Child SCAT5 scores among middle school students.

Design: A cross-sectional study was conducted on a sample of middle school students during the 2017-2018 academic year. Participants were 1,355 students playing competitive school-sponsored sports (ages 11 to 13, M=12.3, SD=0.8; 40.1% girls, 59.9% boys). Certified athletic trainers administered the Child SCAT5 within the first two weeks of the sport season. Children self-reported their health history and language spoken at home.

Results: Gender, age, and language spoken at home were associated with Child SCAT5 scores, but the magnitude of differences were generally small. Specifically, girls endorsed more symptoms (U=199,789.5, p=.003, r=.08) and greater symptom severity (U=201,391.0, p=.006, r=.07) than boys, and performed slightly better than boys on cognitive and balance tasks. Older students performed slightly better than younger students on tests of cognition. Total symptoms [$\chi^2(2)=8.82$, p=.01], symptom severity [$\chi^2(2)=10.70$, p=.01], immediate memory [$\chi^2(2)=37.76$, p<.001], delayed recall [$\chi^2(2)=13.78$, p=.001], and SAC-C total scores [$\chi^2(2)=12.15$, p=.002] differed across language groups.

Conclusions Gender, age, and language spoken in the home are associated with baseline performance on multiple components of the Child SCAT5 among middle school students, though the magnitudes of observed differences are small. Normative reference values are provided for clinicians when interpreting Child SCAT5 scores.

Introduction

The Sport Concussion Assessment Tool (SCAT) was created in 2004 to standardize clinician assessment of sports-related concussion, but it was not designed for use with children.[38] The test was revised in 2008 (SCAT2)[39] and was limited to use with athletes ages 10 years or older. In 2012, the Child SCAT3 was created as a separate, standardized concussion assessment for children ages 5-12.[40] It incorporated tests similar to those of the adult version (i.e., the SCAT3) but included developmental adaptations.[4] Most recently, in 2017, the Child SCAT5 was published and retained the key components of the Child SCAT3 but refined methods for assessing cognition (e.g., the option to re-attempt digits backwards) and balance (e.g., the addition of a single-leg stance).[12] Further, the Child SCAT5 can be used to assess pre-participation baseline performance which could be subsequently used for comparison if an athlete sustains a suspected concussion.[12] Studies examining baseline SCAT2 and SCAT3 scores report differences among athletes based on age,[15–21] gender,[15,19] concussion history,[16,18,19,22] and race.[150] In addition, children with pre-existing health conditions [i.e., Attention-Deficit/Hyperactivity Disorder (ADHD) and learning disorders (LD)] report more concussion-like symptoms and perform worse on neurocognitive testing on baseline concussion assessments, compared to their counterparts who do not have these conditions.[23–27,129] Thus, knowledge of whether and how demographic characteristics may affect scores would support clinical interpretation of Child SCAT5 scores.

To date, limited information is available regarding the associations between Child SCAT5 scores and age, gender, health history, and socio-cultural variables, especially among middle school children. Research informing concussion management practices for middle school children is important because they have nearly triple the incidence of concussion compared to high school athletes [0.75/1,000 athlete exposures (AE)[2] vs 0.24-0.5/1,000 AE[13,14]]. Using a large sample of middle school student-athletes, we sought to: (i) examine potential associations between Child SCAT5 scores and gender, age, and language spoken at home; and (ii) establish normative reference data for the Child SCAT5 among middle school student-athletes.

Methods

Participants. Participants included middle school students in a large, socioculturally diverse public school district[61] in Virginia, USA. As part of George Mason University's Advancing Healthcare Initiatives for Underserved Students (ACHIEVES) project, a total of 1,696 students participating in competitive school-sponsored sports from 2017-2018 were administered the Child SCAT5 during a pre-participation (i.e., "baseline") assessment. Similar to prior studies with the Child SCAT3, we administered the Child SCAT5 to all middle school age students.[15,17] Students did not complete the Child SCAT5 if they had any lower extremity injuries (e.g., ankle sprain) within two months of the baseline collection. Of the total number of students assessed, 233 were either younger than 11 years (n=4) or older than 13 years (n=229) and were excluded. Lastly, all duplicates (n=112), i.e., students who were baselined twice were removed from the final sample. For duplicate cases, results from their first baseline assessment were used. The final sample included 1,355 students (ages 11 to 13, M=12.3, SD=0.8; 40.1% girls, 59.9% boys). Student-athletes included in this study participated in wrestling (n=213; 15.7%), girls' basketball (n=197; 14.5%), boys' basketball (n=154; 11.4%), softball (n=63; 4.6%), baseball (n=60; 4.4%), girls' soccer (n=130; 9.6%), boys' soccer (n=167; 12.3%), volleyball (n=139; 10.3%), and football (n=232; 17.1%). The George Mason University Institutional Review Board approved the construction of the deidentified database for retrospective research purposes and waived assent and consent (See Appendix A).

Instrument. The Child SCAT5 is a standardized assessment tool designed for medical professionals that is used for baseline testing and post-injury evaluations of concussion in children (ages 5-12). The Child SCAT5 dependent variables used in this study were: (i) total number of symptoms endorsed by the child (range: 0-21); (ii) severity of symptoms reported by the child (range: 0-63); (iii) the Standard Assessment of Concussion – Child Version (SAC-C total score, range 0-26), comprised of: immediate memory (range 0-15), concentration (sum of digits backwards [0-1] and days of the week in reverse order [0-5]; range 0-6), and delayed recall scores (range 0-5); and (iv) the Modified Balance Error Scoring System (mBESS) total sum of errors during double, single, and tandem leg stances (range 0-30). Higher scores on cognitive measures (e.g., immediate memory, concentration, and delayed recall) indicate better functioning and higher scores on symptom reporting and balance errors indicate worse functioning.

Testing Procedures. As part of pre-participation assessments, certified athletic trainers (ATs) administered the Child SCAT5 in English to all students participating in after-school sports. All ATs attended multiple training sessions held by study investigators (also ATs) on Child SCAT5 administration and testing protocols. Each student was administered the Child SCAT5 within the first two weeks of practice for the sports season, during a single session in a relaxed and rested state, located in a minimally distracting environment (e.g., classroom, gymnasium, or on the playing field). Students were administered the Child SCAT5 using the standardized instructions. Students self-reported their demographic characteristics (e.g., gender, language spoken at home) as well as their health history (e.g., self-reported no history of concussion, prior hospitalization from a head injury, headache disorder or migraines, LD/dyslexia, ADHD, or depression, anxiety, or other psychiatric disorders). Self-reported language spoken at home was collected as an open-ended demographic question and recoded as a categorical variable with three levels: (i) English only, (ii) Spanish only, and (iii) English and Spanish. A small number of students reported speaking other languages (n=44) and were omitted from the group difference analyses examining the three language groups.

Analyses

Descriptive statistics were used to summarize demographic information including gender, age, health history, and language spoken in the home. Normality tests indicated that all dependent variables (i.e., the Child SCAT5 scores) were non-normally distributed (Shapiro-Wilk, *P's*<.05). Thus, nonparametric analyses were used. Mann-Whitney U tests examined gender differences and Kruskal-Wallis tests evaluated differences between the three languages spoken at home (English only, Spanish only, and English and Spanish) and three age groups (11, 12, and 13 years of age). For statistically significant Kruskal-Wallis tests, planned pairwise comparisons using Mann-Whitney U tests were conducted. The Z values from the Mann-Whitney U tests were used to calculate a nonparametric effect size:[157]

Equation 1. Nonparametric Effect Size

$$(r = \frac{z}{\sqrt{N}})$$

Effect size values were interpreted according to available guidelines (i.e., *r*=.1, small; *r*=.3, medium; *r*=.5, large).[158] These analyses were conducted for the full sample of middle schools students, and a subsample of students without self-reported pre-existing health conditions. Alpha was set *a priori* at *P*<.05.

Normative ranges for the Child SCAT5 components were developed for the sample of students without pre-existing health conditions. Ranges were reported based on percentile ranks consistent with studies of prior SCAT versions.[127,159] The “Broadly normal” scores fell within the 25th or 75th percentile ranks. The “below/above normal” scores were defined as close as possible to the 24th or 76th percentile ranks. The “unusually low/high” scores corresponded with the 10th and 90th percentile ranks. “Extremely low/high” corresponded with the 2nd and 98th percentile ranks. Labels for normative values were anchored by the direction of scores that indicate better performance. That is, greater values of total symptoms, symptom severity, and balance (which reflect worse performance or functioning) are referred to as high scores whereas lower values of immediate memory, digits backwards, concentration, delayed recall, and

SAC-C total score are referred to as low scores. All statistical analyses were performed with SPSS (v. 23, IBM Corp., NY, USA).

Results

Sample demographics are summarized in Table 9. Summary statistics for Child SCAT5 scores, stratified by demographic variables, are presented separately for the full sample and the subsample without pre-existing conditions in Table 10. Normative ranges for the Child SCAT5 components are reported in Table 11.

Table 9. Demographics and self-reported health history characteristics for student-athletes ages 11-13.

	Total N = 1,355	Girls n = 544	Boys n = 811
Age M (SD)	12.3 (0.8)	12.2 (0.8)	12.3 (0.8)
Grade M (SD)	7.1 (0.8)	7.0 (0.8)	7.1 (0.8)
Number of prior concussions M (SD)	0.2 (0.6)	0.1 (0.4)	0.3 (0.7)
Zero prior concussions (n, %)	1,192 (87.9)	499 (91.7)	693 (85.4)
1 prior concussion (n, %)	136 (10.0)	40 (7.4)	96 (11.8)
2 or more prior concussions (n, %)	27 (2.0)	5 (0.9)	22 (1.6)
Hospitalized for head injury (n, %)	91 (6.7)	17 (3.1)	74 (9.1)
Headache disorder/migraines (n, %)	57 (4.2)	27 (5.0)	30 (3.7)
Learning disability/dyslexia (n, %)	19 (1.4)	6 (1.1)	13 (1.6)
ADHD (n, %)	86 (6.3)	19 (3.5)	67 (8.3)
Psychiatric disorder (n, %)	38 (2.8)	23 (4.2)	15 (1.8)

Note. ADHD = Attention-Deficit/Hyperactivity Disorder years.

Table 10. Child SCAT5 scores among student-athletes ages 11-13 by gender, age, and language spoken at home.

		Gender		Age in Years			Language Spoken at Home		
SCAT5 Scores Total Sample	Total (N = 1,355)	Girls (n = 544)	Boys (n = 811)	11 (n = 248)	12 (n = 480)	13 (n = 627)	English (n = 1,052)	Spanish (n = 123)	English & Spanish (n = 136)
Total number of symptoms (M, SD)	7.8 (5.7)	8.4 (5.7)[a]	7.5 (5.7)[a]	8.5 (5.4)	7.8 (6.0)	7.6 (5.7)	8.0 (5.7)[j]	7.7 (5.6)	6.6 (6.0)[j]
Symptom severity score (M, SD)	10.9 (9.4)	11.6 (9.4)[b]	10.4 (9.3)[b]	11.8 (9.4)	11.1 (9.8)	10.3 (9.0)	11.2 (9.4)[k]	10.3 (8.6)[l]	8.8 (8.9)[kl]
Immediate memory, total score (M, SD)	13.8 (1.4)	14.0 (1.2)[c]	13.7 (1.5)[c]	13.6 (1.4)[gh]	13.8 (1.4)[g]	13.9 (1.4)[h]	13.9 (1.3)[mn]	13.1 (1.9)[m]	13.5 (1.4)[n]
Digits Backwards score (M, SD)	3.1 (0.9)	3.1 (0.9)	3.1 (1.0)	3.0 (0.8)	3.1 (1.0)	3.1 (1.0)	3.1 (1.0)	2.8 (0.8)	3.0 (0.9)
Days in reverse order (M, SD)	1.0 (0.1)	1.0 (0.1)	1.0 (0.1)	1.0 (0.1)	1.0 (0.1)	1.0 (0.1)	1.0 (0.1)	1.0 (0.2)	1.0 (0.1)
Concentration total score (M, SD)	4.1 (1.0)	4.1 (0.9)	4.0 (1.6)	4.0 (0.8)	4.0 (1.0)	4.1 (1.0)	4.1 (1.0)	3.9 (0.9)	4.0 (0.9)
Total balance errors (M, SD)	5.0 (3.7)	4.3 (3.3)[d]	5.4 (3.9)[d]	4.9 (3.6)	4.8 (3.7)	5.1 (3.8)	4.9 (3.7)	5.5 (3.8)	5.1 (4.0)
Delayed Recall (M, SD)	3.7 (1.2)	3.8 (1.2)[e]	3.7 (1.2)[e]	3.7 (1.2)	3.7 (1.2)	3.8 (1.1)	3.7 (1.2)[o]	3.8 (1.2)[p]	4.0 (1.1)[op]
SAC-C (M, SD)	21.6 (2.2)	21.9 (1.9)[f]	21.4 (2.3)[f]	21.3 (2.1)[i]	21.5 (2.3)	21.7 (2.1)[i]	21.7 (2.1)[q]	20.8 (2.7)[qr]	21.5 (2.4)[r]
SCAT5 Scores No Pre-Existing Conditions*	(N =1,000)	(n = 433)	(n = 567)	(n = 185)	(n = 328)	(n = 457)	(n = 757)	(n = 95)	(n = 112)
Total number of symptoms (M, SD)	7.5 (5.6)	8.3 (5.7)[a]	6.9 (5.5)[a]	8.0 (5.2)	7.3 (5.7)	7.5 (5.7)	7.6 (5.2)	7.5 (5.4)	6.7 (6.0)
Symptom severity score (M, SD)	10.2 (8.8)	11.4 (9.2)[b]	9.3 (8.4)[b]	10.7 (8.4)	10.1 (9.0)	10.1 (8.8)	10.4 (8.9)	10.0 (8.4)	8.8 (8.7)
Immediate memory, total score (M, SD)	13.8 (1.4)	14.0 (1.2)[c]	13.7 (1.6)[c]	13.5 (1.5)[fg]	13.8 (1.4)[f]	13.9 (1.4)[g]	13.9 (1.3)[ij]	13.1 (2.0)[i]	13.7 (1.4)[j]
Digits Backwards score (M, SD)	3.1 (1.0)	3.1 (0.9)	3.1 (0.9)	3.0 (0.8)	3.1 (1.0)	3.2 (1.0)	3.1 (1.0)[k]	2.9 (0.8)[k]	3.0 (0.8)
Days in reverse order (M, SD)	1.0 (0.1)	1.0 (0.1)	1.0 (0.1)	1.0 (0.0)	1.0 (0.2)	1.0 (0.1)	1.0 (0.1)	1.0 (0.2)	1.0 (0.1)
Concentration total score (M, SD)	4.1 (1.0)	4.1 (1.0)	4.1 (1.0)	4.0 (0.8)	4.1 (1.0)	4.1 (1.0)	4.1 (1.0)	3.9 (0.9)	4.0 (0.9)
Total balance errors (M, SD)	4.8 (3.6)	4.3 (3.3)[d]	5.3 (3.7)[d]	4.7 (3.4)	4.8 (3.7)	4.9 (3.6)	4.7 (3.5)	5.3 (3.6)	5.0 (4.1)
Delayed Recall (M, SD)	3.7 (1.2)	3.8 (1.2)	3.7 (1.2)	3.7 (1.3)	3.7 (1.2)	3.8 (1.2)	3.7 (1.2)[l]	3.7 (1.3)[m]	4.1 (1.1)[lm]
SAC-C (M,SD)	21.6 (2.2)	21.8 (1.9)[e]	21.4 (2.4)[e]	21.3 (2.2)[h]	21.6 (2.3)	21.8 (2.1)[h]	21.7 (2.1)[n]	20.7 (2.9)[no]	21.7 (2.1)[o]

Note. Group means sharing a common superscript (e.g., [a,b,c]) are statistically different at $p<.05$.

*Pre-existing conditions include history of concussion, prior hospitalization from a head injury, headache disorder or migraines, learning disability/dyslexia, Attention-Deficit/Hyperactivity Disorder (ADHD), or depression/anxiety/other psychiatric disorders on the medical history portion of the Child SCAT5. SAC-C = Standard Assessment of Concussion – Child Version

Table 11. Normative ranges for Child SCAT5 components in middle school student-athletes without pre-existing health conditions

		Gender		Age in Years			Language Spoken at Home		
SCAT5 Component (Range of Possible Scores)	Total	Girls	Boys	11	12	13	English	Spanish	English & Spanish
	(N =1,000)	(n = 433)	(n = 567)	(n = 185)	(n = 358)	(n = 457)	(n = 757)	(n = 95)	(n=112)
Total number of symptoms (0-21)									
Broadly Normal	0-12	0-13	0-11	0-12	0-12	0-12	0-12	0-12	0-11
Above Normal	13-16	14-17	12-15	13-16	13-15	13-16	13-16	13-17	12-16
Unusually High	17-19	18-20	16-18	17-19	16-19	17-19	17-19	18-20	17-19
Extremely High	20+	21+	19+	20+	20+	20+	20+	21+	20+
Symptom severity score (0-63)									
Broadly Normal	0-16	0-17	0-15	0-16	0-16	0-15	0-16	0-15	0-15
Above Normal	17-23	18-26	16-22	17-23	17-25	16-23	17-23	16-25	16-24
Unusually High	24-30	27-31	23-28	24-30	26-30	24-30	24-31	26-29	25-28
Extremely High	31+	32+	29+	31+	31+	31+	32+	30+	29+
Immediate memory total score (0-15)									
Broadly Normal	13-15	13-15	13-15	13-15	13-15	13-15	13-15	13-15	13-15
Below Normal	12	12	12	12	12	12	12	12	11-12
Unusually Low	11	11	10-11	10-11	10-11	11	11	8-11	10
Extremely Low	0-10	0-10	0-9	0-9	0-9	0-10	0-10	0-7	0-9
Digits Backwards score (0-5)									
Broadly Normal	2-5	3-5	2-5	3-5	2-5	3-5	3-5	2-5	3-5
Below Normal	-	2	-	-	-	2	2	-	2
Unusually Low	-	1	1	-	1	1	1	-	1
Extremely Low	0-1	0	0	0-2	0	0	0	0-1	0

SCAT5 Component (Range of Possible Scores)	Total	Gender		Age in Years			Language Spoken at Home		
		Girls	Boys	11	12	13	English	Spanish	English & Spanish
	(N =1,000)	(n = 433)	(n = 567)	(n = 185)	(n = 358)	(n = 457)	(n = 757)	(n = 95)	(n=112)
Concentration total score (0-6)									
Broadly Normal	3-6	4-6	3-6	4-6	3-6	4-6	4-6	3-6	4-6
Below Normal	-	3	-	-	-	3	3	-	3
Unusually Low	2	2	2	-	2	2	2	2	-
Extremely Low	0-1	0-1	0-1	0-3	0-1	0-1	0-1	0-1	0-2
Total balance errors (0-30)									
Broadly Normal	0-7	0-6	0-7	0-7	0-7	0-7	0-6	0-7	0-7
Above Normal	8-10	7-9	8-11	8-10	8-10	8-10	7-10	8-11	8-11
Unusually High	11-13	10-12	12-13	11-13	11-13	11-13	11-13	12-13	12-14
Extremely High	14+	13+	14+	14+	14+	14+	14+	14+	15+
Delayed recall (0-5)									
Broadly Normal	3-5	3-5	3-5	3-5	3-5	3-5	3-5	3-5	4-5
Below Normal	2	2	2	2	2	2	2	-	3
Unusually Low	1	1	1	-	1	1	1	2	-
Extremely Low	0	0	0	0-1	0	0	0	0-1	0-2
SAC-C (0-5)									
Broadly Normal	20-26	21-26	20-26	21-26	20-26	21-26	21-26	20-26	21-26
Below Normal	19	19-20	19	19-20	19	19-20	19-20	17-19	19-20
Unusually Low	17-18	18	16-18	16-18	17-18	17-18	17-18	12-16	16-18
Extremely Low	0-16	0-17	0-15	0-15	0-16	0-16	0-16	0-11	0-15

Note. The days in reverse were stated correctly by 98.4% of the sample and were not included in this table. Normative ranges for the Child SCAT5 components were developed for the sample of students without pre-existing health conditions. Ranges were reported based on percentile ranks consistent with studies of prior SCAT versions.[127,159] That is, the "Broadly normal" scores fell within the 25th or 75th percentile ranks. The "below/above normal" scores were defined as close as possible to the 24th or 76th percentile ranks. The "unusually low/high" scores corresponded with the 10th and 90th percentile ranks. "Extremely low/high" corresponded with the 2nd and 98th percentile ranks. Labels for normative values were anchored by the direction of scores that indicate better performance. That is, greater values of total symptoms, symptom severity, and balance (which reflect worse performance or functioning) are referred to as high scores whereas lower values of immediate memory, digits backwards, concentration, delayed recall, and SAC-C total score are referred to as low scores.

Gender Differences. When examining the full sample (N=1,355; Table 10), girls endorsed more symptoms (U=199,789.5, *p*=.003, *r*=.08), and greater symptom severity (U=201,391.0, *p*=.006, *r*=.07), than boys. Girls performed slightly better than boys on immediate memory (U=197,152.5, *p*=.001, *r*=.09), delayed recall scores (U=202,190.5, *p*=.007, *r*=.07), and SAC-C total scores (U=194,682.5, *p*<.001, *r*=.10). Boys committed slightly more balance errors (U=183,249.0, *p*<.001, *r*=.14) than girls. These differences represent negligible to small effect sizes. Genders did not differ on any of the other Child SCAT5 scores (*p*'s>.05).

When limiting the sample to students without pre-existing conditions (n=1,000; Table 10), girls endorsed more symptoms (U=104,682.0, *p*<.001, *r*=.13) and greater symptom severity (U=106,561.0, *p*<.001, *r*=.11) than boys. Girls performed slightly better than boys on immediate memory (U=112,220.5, *p*=.02, *r*=.08) and SAC-C scores (U=113,587.0, *p*=.04, *r*=.06). Boys committed slightly more balance errors (U=103,329.5, *p*<.001, *r*=.14) than girls. All representing negligible to small effect sizes. Genders did not differ on any of the other Child SCAT5 scores (*p*'s>.05).

Age Differences. Age groups differed on immediate memory [$\chi^2(2)=13.88$, *p*=.001] and SAC-C total scores [$\chi^2(2)=8.18$, *p*=.02] for the full sample. Follow-up Mann-Whitney U tests revealed that 11-year-olds performed worse than 12-year-olds (U=52,242.5, *p*=.01, *r*=.10) and 13-year-olds (U=65,831.0, *p*<.001, *r*=.11) on immediate memory. The 11-year-olds also performed worse than 13-year-olds on SAC-C total scores (U=68,551.5, *p*=.01, *r*=.08), all representing small effects. Age groups did not differ on any of the other Child SCAT5 scores (*p*'s>.05). Of note, 12-year-olds did not differ from 13-year-olds on any of the Child SCAT5 scores.

These results were identical when examining those without pre-existing conditions. Namely, age groups differed on immediate memory [$\chi^2(2)=11.62$, $p=.003$] and SAC-C total score [$\chi^2(2)=7.97$, $p=.02$]. The 11-year-olds performed worse than 12-year-olds (U=28,628.0, *P*=.02, *r*=.12) and 13-year-olds (U=35,426.0, *p*=.001, *r*=.13) on immediate memory. The 11-year-olds also performed worse than 13-year-olds on SAC-C total score (U=36,308.5, *p*=.01, *r*=.11), all representing small effects. Age groups did not differ on any of the other Child SCAT5 scores (*p*'s>.05).

Language Differences. For the full sample, the three language groups differed on total symptoms [$\chi^2(2)=8.82$, $p=.01$], symptom severity [$\chi^2(2)=10.70$, $p=.01$], immediate memory [$\chi^2(2)=37.76$, $p<.001$], delayed recall [$\chi^2(2)=13.78$, $p=.001$], SAC-C total scores [$\chi^2(2)=12.15$, $p=.002$]. Post-hoc planned comparisons (Mann-Whitney) revealed that students who reported speaking English at home scored higher than those who reported speaking Spanish at home on immediate memory (U=47,013.0, *p*<.001, *r*=.15) and SAC-C total scores (U=52,428.0, *p*<.001, *r*=.10). Students speaking English at home endorsed more symptoms (U=60,441.5, *p*=.003, *r*=.09) and greater symptom severity (U=59,312.5, *p*=.001, *r*=.09) than students speaking English and Spanish at home. Students speaking English at home also scored significantly higher on immediate memory (U=57,925.5, *p*<.001, *r*=.11) than students speaking English and Spanish at home. Students speaking English and Spanish at home scored significantly higher than students speaking English at home on delayed recall (U=58,175.0, *p*<.001, *r*=.11), representing a small effect size.

Students speaking Spanish at home had a greater symptom severity (U=7184.5, p=.049, r=.12) and scored lower on delayed recall (U=7,069.5, p=.02, r=.14) and SAC-C total score (U=7,030.0, p=.03, r=.14) compared to students speaking English and Spanish. Language groups did not differ on any of the other Child SCAT5 scores (p's>.05).

Among students without pre-existing conditions, statistically significant group differences were noted for immediate memory [$\chi^2(2)=24.84$, $p<.001$], digits backwards [$\chi^2(2)=6.03$, $p=.04$], delayed recall [$\chi^2(2)=14.09$, $p=.001$], and SAC-C total scores [$\chi^2(2)=10.61$, $p=.01$]. Students speaking English at home scored significantly higher than those speaking Spanish at home on immediate memory (U=26.302.5, p<.001, r=.15), digits backwards (U=31,098.0, p=.02, r=.08), and SAC-C total scores (U=28,777.5, p=.001, r=.11), all small effect sizes. Students speaking English at home scored significantly higher on immediate memory (U=36,075.0, p=.01, r=.09) than students speaking both English and Spanish at home. Students speaking both English and Spanish at home scored higher than those who reported speaking only English on delayed recall (U=33,487.5, p<.001, r=.13), and higher than students who speak Spanish only on delayed recall (U=4,457.5, p=.03, r=.15) and SAC-C total score (U=4,209.0, p=.01, r=.18). These represent small effects. Language groups did not differ on any of the other Child SCAT5 scores (p's>.05).

Discussion

The Child SCAT5 is a multimodal concussion assessment instrument.[12] It measures self-reported physical, cognitive, and emotional symptoms; cognitive functioning; and postural stability (i.e., static balance with eyes closed). The two recommended methods for interpreting Child SCAT5 performance following concussion are to compare a child's performance to his or her own personal, pre-injury baseline or compare obtained results to normative reference values.[28] Often personal baseline preseason test results are not available, thus normative reference values can help clinicians interpret test performance and assist in concussion management. This study examined whether Child SCAT5 symptom scores and test performances are associated with demographic characteristics and health history in middle school children. Our findings provide clinicians normative reference values for interpreting Child SCAT5 results stratified by demographic characteristics.

Our findings suggest that gender, age, and language spoken at home, are associated with Child SCAT5 test results; however, the magnitudes of the observed differences were generally small to negligible. Regarding gender, girls reported more symptoms and a higher symptom severity than boys, which is consistent with prior studies.[160,161] In addition, girls outperformed boys on some tests of cognition and balance, which is also consistent with prior literature.[15,17,19,128] Further, there is considerable evidence that older children perform better on the cognitive tests used in concussion assessments than younger children.[16,17,19,27] Although we had a limited age range, older middle school students in our sample had marginally better cognitive scores than younger students. Specifically, very small differences were noted between 11-year-olds and 12-13-year-olds and no differences were observed between students ages 12 and 13 years on any Child SCAT5 component. Prior studies have found sizeable age effects, but those studies constructed larger age cohorts and compared children in different developmental phases, such as comparing children ages 5-7 to those ages 11-13.[15,17] At present, normative data for the Child SCAT3 and SCAT3 do not include reference values stratified by language spoken by the child. In our study, baseline Child SCAT5 symptoms and cognitive scores differed among middle school students based on their language spoken at home. Specifically, students speaking English at home reported slightly more symptoms than students speaking Spanish at home, and performed marginally better on cognitive tasks than Spanish speakers. Lastly, scores varied when the sample was constrained to include only students without pre-existing health conditions. These variations may be noteworthy, because prior literature has found that individuals with pre-existing health conditions perform differently on the Child SCAT3.[23–27,129]

Our findings are similar in many ways to previous research on the performance of children and adolescents using the SCAT2[19,22] and the Child SCAT3.[15,17,20] Compared to prior work on the Child SCAT3, our findings show similar scores for total symptoms[15,20] and symptom severity.[15,20] The middle school participants endorsed very similar symptom severity scores [mean (M)=10.9±9.4] to those reported by Brooks and colleagues[15] (M=11.3±9.0), Porter and colleagues[20] (M=11.4±8.4), and Nelson and colleagues[17] (M=9.5±8.0). Our participants' immediate memory, concentration, and delayed recall scores are similar to previous findings.[15,17,20] The Child SCAT5 does not include an Orientation section, which was incorporated in the Child SCAT3 to calculate the SAC-C total scores; for this reason, our SAC-C total scores are lower than those previously reported.[15,17,20] The total balance errors for the present middle school sample (M=5.0±3.7) are considerably higher than those reported by Brooks et al.

(M=0.76±1.2),[15] Porter et al. (M=1.6±2.2),[20] and Nelson et al. (M=1.1±1.3).[17] This is largely due to the inclusion of the single leg stance in the mBESS assessment for the Child SCAT5, whereas the Child SCAT3 did not include this component. Interestingly, Nelson et al.[17] also assessed children using the SCAT3 (i.e., the adult version), which includes the single leg stance, and reported similar balance errors to our findings (M=3.9±3.2).

The Concussion in Sport Group has called for researchers to develop more normative data on concussion assessment tools that includes athletes of all genders, ages, and languages.[28] At present, no study has examined Child SCAT5 performance following injury. When an athlete's baseline scores are not available, normative comparisons have similar sensitivity to individual baseline comparisons[93] and may assist with the clinical management of concussion.[28] Our study presents score ranges stratified by demographic characteristics for what is considered to be "normal" performance, which can assist clinicians interpreting post-injury Child SCAT5 results. As previously mentioned, there were statistically different scores observed by demographic characteristics, but these differences were small in terms of magnitude (see Table 11). There is some variability in the normative rank classifications of middle school students based on their demographic characteristics. For example, there is a greater range of "broadly normal" symptom severity for girls (0-17) than boys (0-15). However, the ranges in scores that represent other components of the Child SCAT5 are marginally different, such as SAC-C total scores that are considered "broadly normal" for students speaking English (21-26) versus

Spanish (20-26) at home. Research informing the clinical utility of these score cutoffs within this population is needed.

Limitations. This study has several limitations. Our data were collected from a highly diverse and economically disadvantaged pediatric sample and may not be generalizable to certain groups of pediatric athletes. In addition, our study investigated middle school students between the ages of 11 and 13, and thus the results are not generalizable to younger children. The administration and data collection process were standardized; however, some sports were tested indoors (e.g., wrestling, basketball, and volleyball) and some were tested outdoors (e.g., soccer, football, baseball, and softball) depending on the environment in which practice was conducted. Further, the Child SCAT5 includes a parent-report symptom scale. However, baseline parent reported symptoms were not included in this study because we did not have consistent access to parents.

Lastly, Table 11 includes normative ranges for the middle school children without pre-existing health conditions. Previous research has suggested the use of normative data may be appropriate when managing concussions for children.[70,162,163] However, comparing children with pre-existing health conditions to normative data based on children without such conditions may not be ideal; it may be preferable to compare those athletes' post-injury data to their own baseline data.[70] Also, Table 11 is limited in that it provides suggested ranges by gender or language or age, not based on combinations of these variables.

Conclusion

We provide normative baseline data from a large cohort of middle school students, suggesting ranges of normal and abnormal scores for health care providers to reference when interpreting Child SCAT5 performance. There is evidence of minor, small magnitude performance differences based on demographic characteristics. Future research should investigate the clinical utility of these normative ranges in comparison to using personal pre-injury baseline scores for post-injury evaluations.

Chapter Four – Study II: Interpreting Change on the Child Sport Concussion Assessment Tool, 5th Edition

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Abstract

Objectives: The Child Sport Concussion Assessment Tool 5th Edition (Child SCAT5) is designed for use with children between the ages of 5 and 12 who are known or suspected to have sustained a concussion. Proper use of the test requires an understanding of its test-retest reliability. The purpose of this study is to examine the one-year test-retest reliability of Child SCAT5 scores and to provide recommendations for interpreting change on its component tests.

Design: A prospective cohort study was conducted from August 2017 to May 2019 as part of George Mason University's Advancing Healthcare Initiatives for Underserved Students (ACHIEVES) Project.

Methods: Students were recruited from nine middle schools in a large public-school district in Virginia, USA. Participants were 219 students (ages 11 to 12, M=11.7, SD=0.5; 52.1% girls, 47.9% boys) playing competitive school-sponsored sports during 2017-2018 and 2018-2019 academic years who underwent baseline testing with the Child SCAT5 each school year. Certified athletic trainers administered the Child SCAT5 within the first two weeks of the sport season.

Results: The test-retest reliabilities of each Child SCAT5 component were low (r_s=024-0.38). However, most middle school athletes (69%–85%) scored within the same normative classification range upon re-assessment. There were no significant differences between the proportions of athletes who improved or declined in their normative ranking at retest. Regarding reliable change, fewer than 20% of this sample had the following test-retest difference scores: +5 total symptoms, +7 symptom severity, -2 in SAC-C total score, and +4 total mBESS balance errors.

Conclusions: The Child SCAT5 component scores had low test-retest reliability over a one-year period. We provide the distributions of Child SCAT5 raw score changes upon retesting to help clinicians identify changes that are uncommon in uninjured samples.

Introduction

The Child Sport Concussion Assessment Tool, 5th Edition (Child SCAT5) is a multimodal assessment instrument designed to measure symptoms, cognition [Standardized Assessment of Concussion (SAC-C)], and postural stability [Modified Balance Error Scoring System (mBESS)] in children.[164] The Child SCAT5 is designed for repeat administration including baseline, preseason assessments and serial post-injury evaluations. The interpretation of score changes on concussion assessment measures, such as the Child SCAT5, requires information regarding the psychometric properties of the test including temporal stability (e.g., test-retest reliability), which allows for empirically-derived guidance regarding magnitudes of change that might be clinically meaningful.[88] Poor test-retest reliability contributes to score changes that are influenced by a variety of factors, collectively conceptualized as "measurement error," rather than true change in functioning.[165] This is especially important to consider when evaluating pediatric concussion assessment measures due to the rapid developmental changes children can experience yearly.[88,122] Scores derived from previous iterations of the SCAT (i.e., SCAT3 and Child SCAT3) are potentially influenced by practice effects[28] and low test-retest reliability.[29,166] Such limitations may also apply to the Child SCAT5, but research examining the test-retest reliability of the Child SCAT5 is lacking.

In addition to understanding the temporal stability of test scores, knowing the frequency of a certain magnitude of score change among uninjured children who are retested is useful in both clinical and research contexts. Specifically, understanding the magnitude of change on retesting that is "common" and "typical" among normative groups can inform the clinical interpretation of the test results.[29,88,167] To date, no prior study has investigated score change upon Child SCAT5 retesting. To better understand the clinical utility of the Child SCAT5, we sought to investigate (i) the one-year test-retest reliability and (ii) score changes on the Child SCAT5 among middle school-age student-athletes.

Methods

Participants. This study includes middle school-age student-athletes participating in school-sanctioned sports in a large, socioculturally diverse public school district in Virginia.[61] A total of 1,146 athletes ages 11-12 completed baseline Child SCAT5 assessments for the 2017-2018 ("test") or 2018-2019 ("retest") academic years. Of the 1,146 student-athletes assessed, 221 student-athletes completed both a test and retest baseline assessment, and 219 completed the test and retest assessments approximately one academic year apart (test-retest interval range 289-406 days, M=367.2, SD=14.3). The final sample included 219 children (19.1% of the total cohort). At the first baseline assessment, all of the children were 11 or 12 years old (M=11.7 years, SD=0.5; 52.1% girls, 47.9% boys). They participated in girls' basketball (n=61; 27.9%), wrestling (n=39; 17.8%), boys' basketball (n=36; 16.4%), girls' soccer (n=35; 16.0%), baseball (n=22; 10.0%), softball (n=12; 5.5%), boys' soccer (n=8; 3.7%), and football (n=6; 2.7%). The George Mason University Institutional Review Board approved the construction of the deidentified database for retrospective research purposes and waived assent and consent (See Appendix A).

Measure. The Child SCAT5 is a concussion assessment instrument used by health care providers to collect information about pre- (i.e., "baseline") and post-concussion symptom presentation and functioning.[164] The Child SCAT5 includes a self-report symptom questionnaire where each symptom is rated from 0-3 (i.e., "not at all/never;" "a little/rarely;" "somewhat/sometimes;" "a lot/often"). The tool generates several scores: (i) total number of symptoms endorsed (range: 0-21); (ii) total symptom severity (range: 0-63); (iii) SAC-C total score, (range 0-26), which is the sum of: immediate memory (range 0-15), concentration (which is the sum of digits backwards [0-1] and days of the week in reverse order [0-5]; range 0-6), and delayed recall scores (range 0-5); and (iv) the mBESS total sum of errors during double, single, and tandem leg stances (range 0-30). These scores represent the dependent variables for this study. Higher scores on symptom reporting and balance errors indicate worse functioning and higher scores on cognitive measures indicate better functioning. Of note, for the Immediate Memory and Digits Backwards subtests, the raters randomly chose one of six potential options of stimuli provided in the Child SCAT5.

Procedures. Certified athletic trainers (subsequently referred to as "raters") administered the Child SCAT5 in English to student-athletes participating in school-sanctioned sports across the two school years. All raters received training on the administration and scoring of the Child SCAT5. All baseline Child SCAT5 assessments were conducted while the student-athlete was in a relaxed state, a minimally distracting environment, and during the first two weeks of sports participation, consistent with prior procedures (P. M. Kelshaw, unpublished data, December 2019). Demographic characteristics and health history were self-reported. For some analyses, student-athletes were grouped based on whether or not they reported a history of pre-existing health condition [i.e., >0 prior diagnosed concussions, prior hospitalization from a head injury, headache disorder or migraines, Learning disabilities/dyslexia, Attention-Deficit/Hyperactivity Disorder (ADHD), and depression, anxiety, or other psychiatric disorders]. Student-athletes also self-reported their primary language spoken at home, which was collected as an open-ended question and dichotomized by researchers (English as primary language spoken at home or not). We included this variable because language is associated with differences in baseline performance on the Child SCAT5 (P. M. Kelshaw, unpublished data, December 2019).

Analyses

Descriptive statistics were calculated for all dependent variables, as well as stratified by demographic characteristics [i.e., gender, age, health history, and rater (same or different)]. Normality tests indicated that all Child SCAT5 scores were non-normally distributed (Shapiro-Wilk, p's<.05). Thus, nonparametric tests were used. Nonparametric effect sizes[157] were calculated ($r = \frac{z}{\sqrt{N}}$) using the z-values from the Wilcoxon Signed-Rank and Mann Whitney U tests (described below) and were interpreted according to available guidelines (i.e., r=.1, small; r=.3, medium; r=.5, large).[158] All statistical analyses were performed with SPSS (v. 23, IBM Corp., NY, USA). Alpha was set a priori at *p*<.05. All figures were generated with RStudio (RStudio, Inc., Boston, MA, USA).

Test-Retest Reliability and Raw Score Differences. Temporal stability/test-retest reliability was evaluated with Spearman Rho (r_s) coefficients. The strength of the reliability coefficients was interpreted using conventional guidelines (i.e., ≥.90=very high; .80-.89=high; .70-.79=adequate; .60-.69=marginal; <.60=low).[83,84] These analyses were conducted for the full sample of middle school student-athletes, the subsample of student-athletes without pre-existing health conditions, and separately for student-athletes who were assessed by the same rater or by a different rater. Wilcoxon Signed-Rank tests were used to examine differences between test and retest Child SCAT5 scores.

Test-Retest Difference Scores. To examine raw score change on Child SCAT5 scores (i.e., "individual change"), consistent with prior published literature,[29,168] test-retest difference scores were calculated by subtracting Year 1 (test) baseline scores from Year 2 (retest) baseline scores, in order to illustrate the normal test-retest variability in an uninjured middle school sample. Score changes were classified as "uncommon" if fewer than 20% of the study sample obtained comparable or more extreme test-retest difference scores. Lastly, reliable change estimates were derived from the standard error difference (S_{diff}) of standard error of the measures (SEM), per by Iverson et al.,[91] to create confidence intervals for the test-retest difference scores.[92,169] Reliable change estimates were calculated using the following equations:

Equation 2. Reliable Change Estimates.

$$SEM_{Test} = SD_{Test}\sqrt{r_s - 1}$$

$$SEM_{Retest} = SD_{Retest}\sqrt{r_s - 1}$$

$$S_{diff} = \sqrt{SEM_{Test}^2 + SEM_{Retest}^2}$$

To interpret the measurement error (i.e., S_{diff}), confidence intervals (CI) for interpreting reliable change were generated by multiplying the S_{diff} by z-scores of 1.28 (80% CI), 1.64 (90% CI), and 1.96 (95% CI).[91,92] Mann Whitney U tests were used to assess between-group differences on test-retest difference scores between raters (same or different), genders (girl/boy), history of pre-existing health conditions (yes/no), and English primary language spoken at home (yes/no).

Change in Normative Classification. As a measure of score change relative to normative expectations (i.e., “normative change”), retest scores were characterized according to various normative classifications (e.g., broadly normal, below/above normal, usually low/high, extremely low high; see definitions in Table 17) generated from our large cohort of 1,000 baseline Child SCAT5’s collected during the 2017-2018 school year (P. M. Kelshaw, unpublished data, December 2019). Worse performance/functioning is represented by higher percentiles on total symptoms, symptom severity, and balance, and low percentiles on cognitive tasks (immediate memory, digits backwards, concentration, delayed recall, and SAC-C total score). These scores were normed based on participant age and gender (separately). Percentages of students who fell within the same normative category, improved, or declined in normative classification upon retest were calculated. A Chi Square test was used to compare the proportion of student-athletes who either improved or declined in normative categories at retest.[170]

Results

Sample demographics are summarized in Table 12. Summary demographics are provided for the total sample and by gender.

Table 12. Demographic and self-reported health history characteristics for student-athletes ages 11-12, as reported on year 1 (i.e., "Test") of baseline Child SCAT5 assessments.

	Total N = 219	Girls n = 114	Boys n = 105
Age M (SD)	11.7 (0.5)	11.7 (0.5)	11.7 (0.5)
Grade M (SD)	6.4 (0.5)	6.4 (0.5)	6.5 (0.5)
English language spoken at home (n, %)	160 (73.1)	83 (79.8)	77 (67.5)
Pre-existing health condition (n, %)	69 (31.5)	33 (28.9)	36 (34.3)
Number of prior concussions M (SD)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)
Zero prior concussions (n, %)	196 (89.5)	103 (90.4)	93 (88.6)
1 prior concussion (n, %)	22 (10.0)	10 (8.8)	12 (11.4)
2 or more prior concussions (n, %)	1 (0.5)	1 (0.9)	0 (0.0)
Hospitalized for head injury (n, %)	17 (7.8)	4 (3.5)	13 (12.4)
Headache disorder/migraines (n, %)	8 (3.7)	8 (7.0)	0 (0.0)
Learning disability/dyslexia (n, %)	2 (0.9)	1 (0.9)	1 (1.0)
ADHD (n, %)	14 (6.4)	4 (3.5)	10 (9.5)
Psychiatric disorder (n, %)	6 (2.7)	3 (2.6)	3 (2.9)

Note. Pre-existing health condition was defined as the number of student-athletes endorsing one or more of the health history questions on the Child SCAT5 [history of concussion, prior hospitalization from a head injury, headache disorder or migraines, Learning disabilities/dyslexia, Attention-Deficit/Hyperactivity Disorder (ADHD), and depression, anxiety, or other psychiatric disorders]. M = Mean, SD = Standard Deviation.

Test-Retest Reliability. All Child SCAT5 component scores had poor one-year temporal stability (i.e., test-retest reliability) across the full sample (see Table 13), sample without pre-existing health conditions (see Table 14), sample with the same rater, and sample with different raters (see Table 15). Excluding those individuals who had pre-existing conditions did not change the test-retest coefficients (r_s range=.21-.39) Notably, there are marginal differences in reliability coefficients across the symptoms, cognitive, and balance assessments.

Table 13. Descriptive statistics and stability coefficients for the Child SCAT5 for the full sample of middle school students ages 11-12 (n=219).

	Baseline Assessments 2017-2018 (Test)					Baseline Assessments 2018-2019 (Retest)					Correlation Coefficients (r_s, p-value)			
Child SCAT5 Component	Range	M	Md	SD	IQR	Range	M	Md	SD	IQR	n=219[a]	n=149[b]	n= 81[c]	n=69[d]
Symptom														
Total Score	0-21	7.7	7	5.8	9	0-21	7.7	7	5.8	9	.35, p<.001	.21, p=.01	.15, p=.19	.33, p=.01
Severity	0-41	10.6	8	9.3	14	0-40	10.4	8	9.1	13	.37, p<.001	.23, p=.004	.18, p=.10	.35, p=01
SAC-C														
Total Score	8-26	21.5	22	2.2	3	16-26	22.2	22	2	3	.35, p<.001	.35, p<.001	.44, p<.001	.29, p=.01
Immediate Memory	6-15	13.7	14	1.5	2	9-15	14.1	15	1.2	1	.38, p<.001	.39, p<.001	.37, p=.001	.50, p<.001
Digits Backwards	1-5	3.1	3	0.9	1	1-5	3.3	3	0.9	1	.34, p<.001	.27, p=001	.27, p=.01	.25, p=.04
Concentration	1-6	4	4	0.9	2	1-6	4.3	4	0.9	1	.35, p<.001	.28, p<.001	.33, p=.003	.24, p=.04
Delayed Recall	0-5	3.8	4	1.2	2	0-5	3.8	4	1.1	2	.34, p<.001	.34, p<.001	.33, p=.003	.33, p=.01
mBESS														
Total	0-14	4.2	4	3.4	4	0-20	4.7	4	3.6	4	.35, p<.001	.34, p<.001	.26, p=.02	.44, p<.001
Tandem Leg	0-5	1	1	1.2	2	0-10	1.2	1	1.6	2	.24, p<.001	.23, p=.01	.26, p=.02	.26, p=.04
Single Leg	0-10	3.2	2	2.7	3	0-10	3.5	3	2.6	3	.35, p<.001	.32, p<.001	.25, p=.03	.38, p=.002

Note. SAC-C = Standardized Assessment of Concussion - Child Version, mBESS = Modified Balance Error Scoring System, r_s, = spearman rho stability coefficient. A majority of middle school student-athletes (99.5%) did not commit any errors on the double leg stance for the mBESS, and 98.2% correctly listed the days of the week in reverse order for test and retest assessments, as such these values are not included in this table.

[a]Full sample (n=219).

[b]Sample without pre-existing health conditions as collected on the Child SCAT5 (n=150).

[c]Sample with the same rater form test to retest assessments (n=81).

[d]Sample with a different rater from test to retest assessments (n=69).

Table 14. Descriptive statistics and stability coefficients for the Child SCAT5 for middle school students ages 11-12 without pre-exiting health conditions (n=150).

	Baseline Assessments 2017-2018 (Test)					Baseline Assessments 2018-2019 (Retest)					
Child SCAT5 Component	Range	M	Md	SD	IQR	Range	M	Md	SD	IQR	r_s, p-value
Symptom											
Total Score	0-21	7.1	7	5.8	9.3	0-21	7.4	6	5.9	10	.21, p=.01
Severity	0-41	9.7	7	9.3	13	0-39	9.9	8	9.2	13.3	.23, p=.004
SAC-C											
Total Score	8-25	21.6	22	2.3	3	16-26	22.1	22	2.1	2	.35, p<.001
Immediate Memory	6-15	13.8	14	1.4	2	9-15	14.1	15	1.3	1	.39, p<.001
Digits Backwards	1-5	3	3	0.8	0.3	1-5	3.3	3	0.9	1	.27, p=001
Concentration	1-6	4	4	0.9	0	1-6	4.3	4	0.9	1	.28, p<.001
Delayed Recall	0-5	3.8	4	1.2	2	0-5	3.7	4	1.2	2	.34, p<.001
mBESS											
Total	0-14	4.3	4	3.4	4	0-18	4.6	4	3.3	4	.34, p<.001
Tandem Leg	0-5	1.1	1	1.2	2	0-8	1.2	1	1.5	2	.23, p=.01
Single Leg	0-10	3.2	3	2.7	3	0-10	3.4	3	2.5	3.3	.32, p<.001

Note. SAC-C = Standardized Assessment of Concussion - Child Version, mBESS = Modified Balance Error Scoring System, r_s, = spearman rho stability coefficient. A majority of middle school student-athletes (99.3%) did not commit any errors on the double leg stance for the mBESS, and 98.0% correctly listed the days of the week in reverse order for test and retest assessment, as such these values are not included in this table.

Table 15. Descriptive statistics and stability coefficients stratified by same or different raters.

	Same Rater (n=81)			Different Rater (n=69)		
Child SCAT5 component	Test M (SD)	Retest M (SD)	r_s, p-value	Test M (SD)	Retest M (SD)	r_s, p-value
Symptom						
Total Score	7.4 (6.4)	8.0 (6.1)	.15, p=.19	6.8 (5.1)	5.9 (5.4)	.33, p=.01
Severity	10.1 (10.1)	11.0 (9.8)	.18, p=.10	9.1 (8.2)	7.4 (7.7)	.35, p=01
SAC-C						
Total Score	21.7 (2.3)	22.0 (2.2)	.44, p<.001	21.5 (2.3)	22.5 (2.0)	.29, p=.01
Immediate Memory	14.0 (1.4)	14.0 (1.3)	.37, p=.001	13.6 (1.4)	14.2 (1.2)	.50, p<.001
Digits Backwards	3.0 (0.8)	3.1 (0.9)	.27, p=.01	3.0 (0.9)	3.5 (0.9)	.25, p=.04
Concentration	4.0 (0.8)	4.1 (0.9)	.33, p=.003	4.0 (1.0)	4.5 (1.0)	.24, p=.04
Delayed Recall	3.7 (1.2)	3.6 (1.2)	.33, p=.003	3.8 (1.3)	4.0 (1.1)	.33, p=.01
mBESS						
Total	3.8 (3.3)	4.4 (2.9)	.26, p=.02	4.9 (3.4)	4.8 (3.8)	.44, p<.001
Tandem Leg	0.9 (1.2)	1.3 (1.2)	.26, p=.02	1.3 (1.2)	1.1 (1.7)	.26, p=.04
Single Leg	2.9 (2.6)	3.1 (2.2)	.25, p=.03	3.7 (2.7)	3.7 (2.8)	.38, p=.002

Note. SAC-C = Standardized Assessment of Concussion - Child Version, mBESS = Modified Balance Error Scoring System, r_s, = spearman rho stability coefficient. A majority of middle school age student-athletes (99.3%) did not commit any errors on the double leg stance for the mBESS, and 98.0% correctly listed the days of the week in reverse order for test and retest assessment, as such these values are not included in this table.

Raw Score Differences. For the full sample of middle school student-athletes (n=219), there were statistically significant differences between test and retest scores of Child SCAT5 cognition and balance components, such that scores at retest were better than test, with small effect sizes [SAC-C total score (Z=-3.86, p<0.001, r=-0.26), immediate memory (Z=-2.87, p=0.004, r=-0.19) digits backwards (Z=-3.83, p<0.001, r=-0.26), concentration (Z=-3.81, p<0.001, r=-0.26), total balance (Z=-2.16, p=0.03, r=-0.15), and single leg balance scores (Z=-2.06, p=0.04, r=-0.14)]. For student-athletes without pre-existing health conditions (n=150), retest scores were better for SAC-C total score (Z=-2.50, p=0.01, r=-0.20), digits backwards (Z=-3.24, p=0.001, r=-0.26), and concentration (Z=-3.28, p=0.001, r=-0.26), with similarly small magnitude effects. These statistical differences appear small to negligible when examining the mean and median values per Child SCAT5 component across test and retest (see Table 13). Raincloud plots[171,172] illustrate the distribution of raw scores upon test and retest assessments (Figures 1-3).

Raw Score Differences by Raters. Children with the same rater for both test and retest (n=81) scored significantly higher (i.e., performed worse) on retest for total balance (Z=-2.10, p=0.04, r=-0.23) and tandem leg stance (Z=-2.25, p=0.02, r=-0.25) with small magnitude differences. Student-athletes with different raters (n=69) scored significantly better on retest assessments on SAC-C (Z=-3.39, p<0.001, r=-0.41), immediate memory (Z=-3.45, p=0.001, r=-0.42), digits backwards (Z=-3.26, p=0.001, r=-0.39), and concentration (Z=-3.11, p=0.001, r=-0.37), each representing medium effect sizes. However, examining the mean score differences between the time points on these variables suggests that a single question or point may be responsible for these statistically significant findings, and thus, they may not be clinically meaningful (See Table 15).

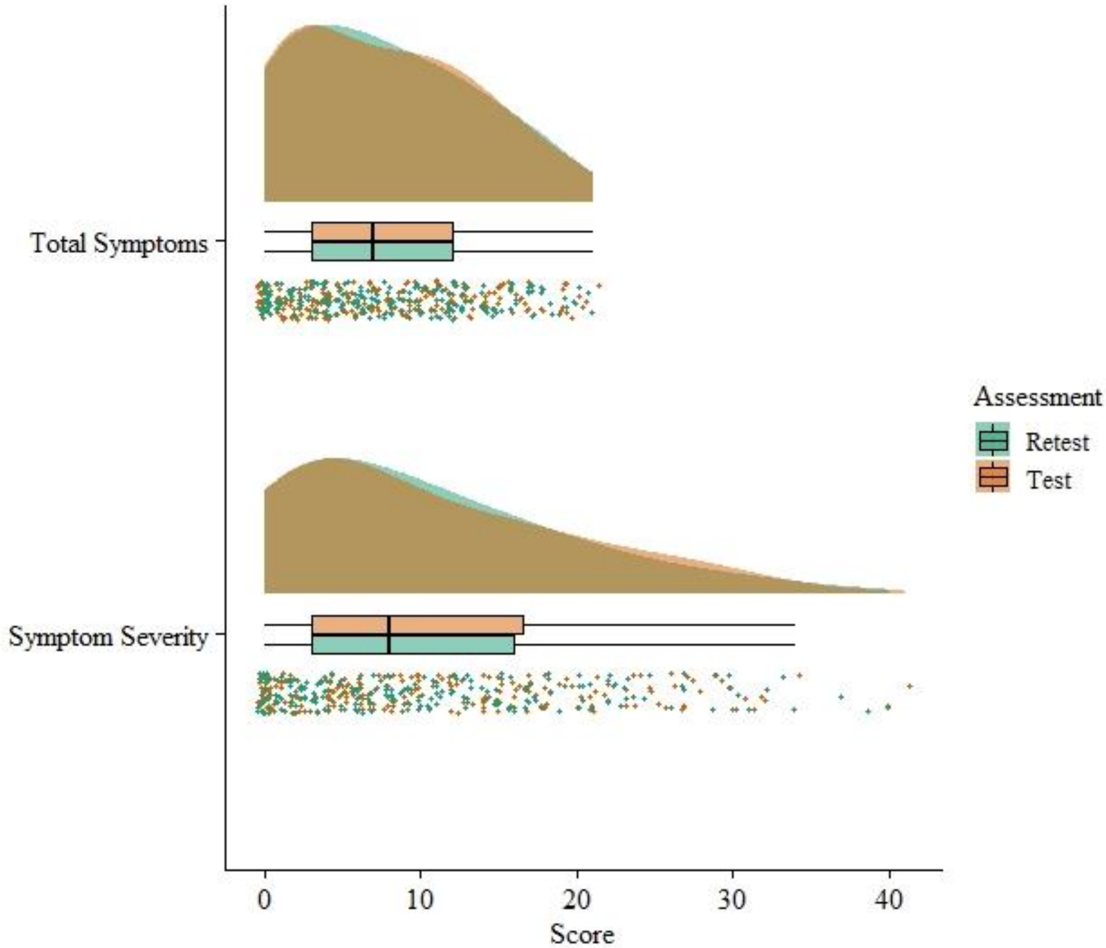

Figure 1. Raincloud plot of raw Child SCAT5 total symptoms and symptom severity scores at test and retest assessments.

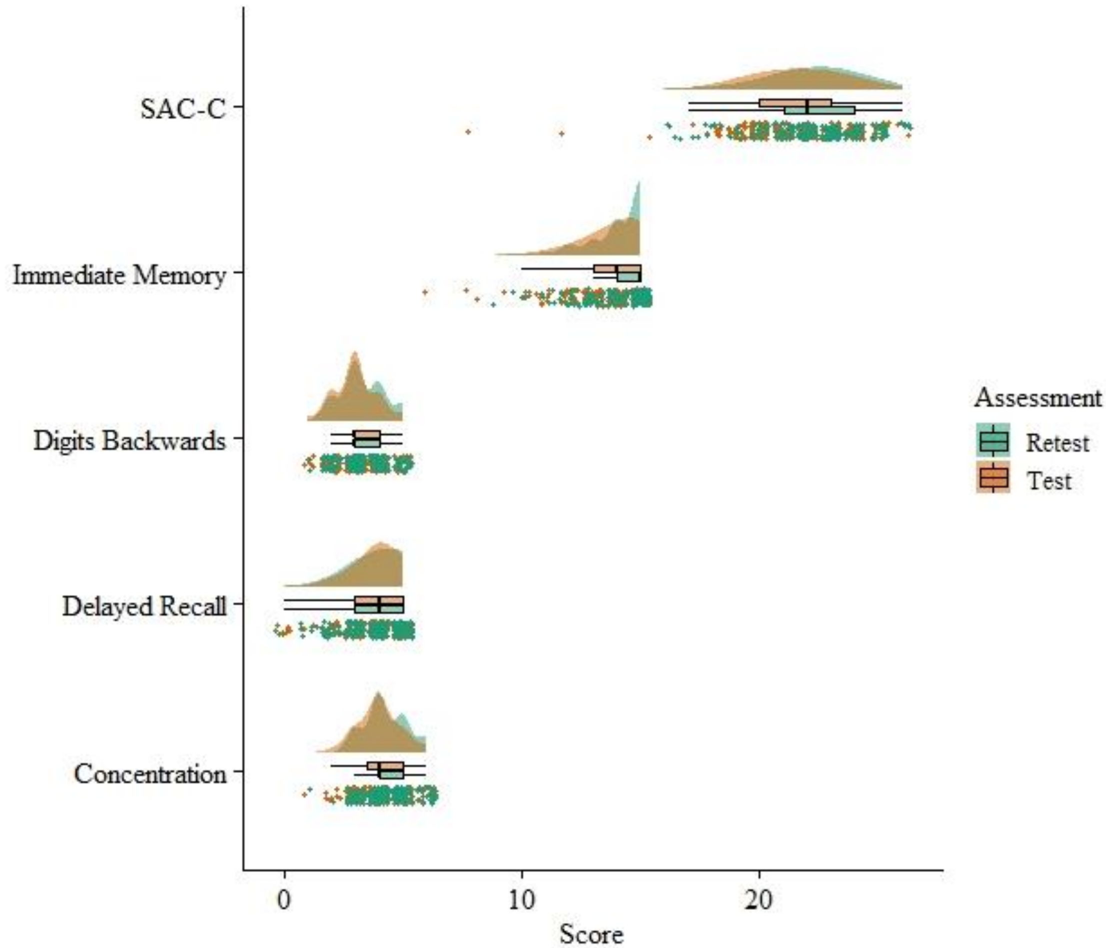

Figure 2. Raincloud plot of raw Child SCAT5 cognitive scores at test and retest assessments.

Note. A majority of middle school age student-athletes (98.2%) correctly listed the days of the week in reverse order, as such these values are not included in this figure. SAC-C = Standardized Assessment of Concussion - Child Version.

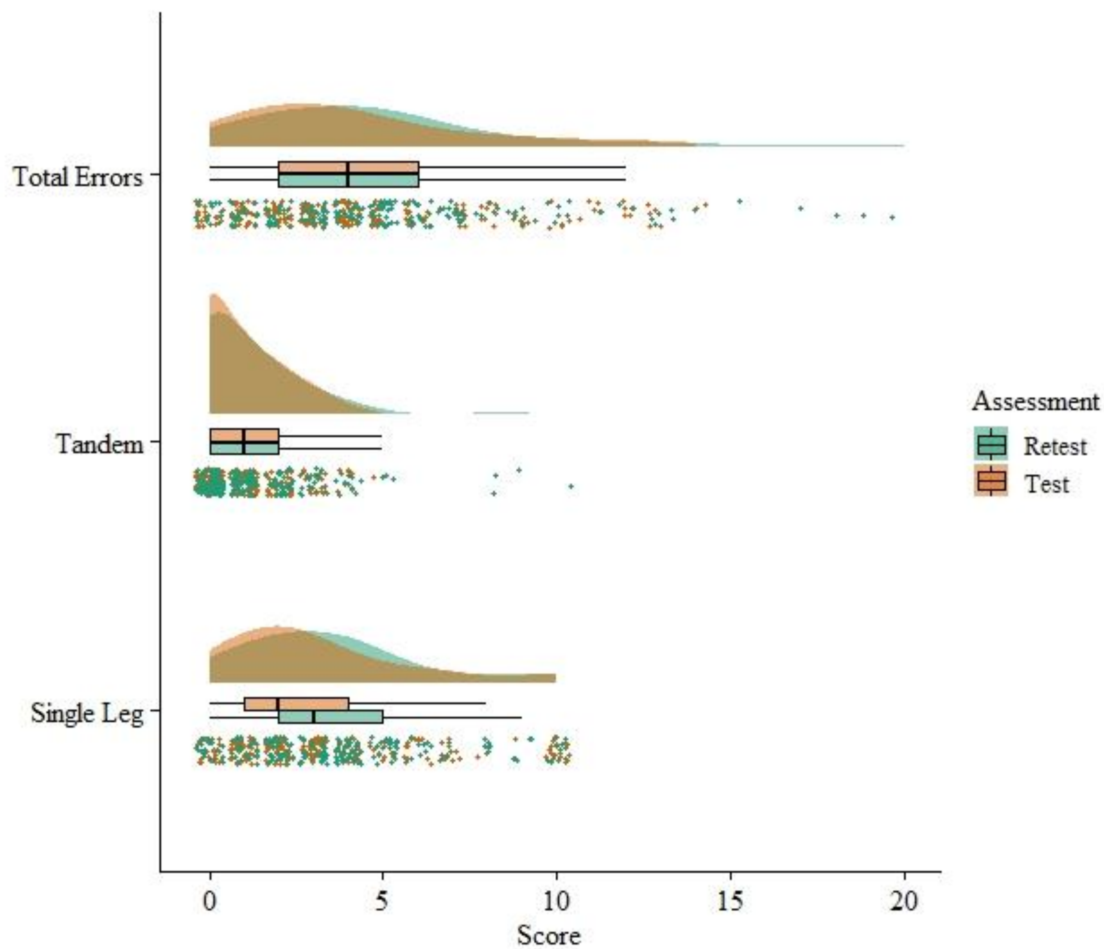

Figure 3. Raincloud plot of raw Child SCAT5 balance scores at test and retest assessments.

Note. A majority of middle school age student-athletes (99.5%) did not commit any errors on the double leg stance, as such these values are not included in this figure. mBESS = Modified Balance Error Scoring System.

Test-Retest Difference Scores. The test-retest difference score descriptive statistics and reliable change estimates with corresponding confidence intervals are presented in Table 16. Examining the calculated reliable change confidence intervals (from the standard error of difference scores), the most liberal confidence intervals (70%) for estimating change on the Child SCAT5 are as follows: Total symptoms ± 7, symptom severity ± 11, SAC-C total score ± 2, immediate memory ± 1, digits backwards ± 1, concentration ± 1, delayed recall ± 1, mBESS total errors ± 4, mBESS tandem stance ± 2, mBESS single leg stance ± 3. Using a different methodology for examining reliable change, based on the *natural distribution* of the difference scores, yields reasonably similar, but not identical, results for what would be expected for 15% in each tail, as compared to the 70% confidence interval for the computed reliable change. If one adopted a strategy for identifying worsening on retest that maintained specificity at approximately 80%, using the natural distribution of difference scores, than approximately 20% of the middle school cohort exhibited the following worsening in scores: Total symptoms + 5, symptom severity + 7, SAC-C total score - 2, immediate memory - 1, digits backwards - 1, concentration - 1, delayed recall - 1, mBESS total errors + 4, mBESS tandem stance + 1, mBESS single leg stance + 2. The individual test-retest difference score distributions are presented in Figure 4.

When comparing the test-retest difference scores between groups (same vs. different rater), student-athletes with different raters experienced greater individual change (specifically improvement) on the SAC-C total score (U=2092.0, p=0.007, r=-0.22) and immediate memory (U=1972.0, p=0.001, r=-0.26) than student-athletes with the same rater, each representing small effect sizes. Student-athletes with the same rater experienced greater test-retest change (more errors) on total mBESS scores (U=2,259.5, p=0.04, r=-0.17) and tandem stance scores (U=2,113.5, p=0.008, r=-0.22) with small effects, than those with a different rater. There were no statistically significant differences by gender, English as primary language spoken at home, or student-athletes reporting one or more pre-existing health conditions on Child SCAT5 test-retest difference scores.

Recommendation for Interpreting Worsening on the Child SCAT5. The natural distribution of test-retest change scores, illustrated in Figure 4, was used to select cutoffs for suspecting that the middle school sample might have worse symptoms, cognitive functioning, or balance on retesting compared to their original baseline. If a student-athlete reported 5 or more symptoms on retesting, that occurred in 40 children (base rate = 18.3%) in the total sample. Thus, 81.7% of student-athletes did not show this worsening in symptoms on retest. Similarly, if the symptom severity score worsened by 7, that occurred in 42 student-athletes (base rate = 19.2%). Worsening by 2 or more points on the SAC-C occurred in 16.9% of the sample, and worsening by 4 or more points on the mBESS occurred in 19.0% of the sample. Each of these cutoffs were chosen to approximate a specificity of 80%.

Table 16. Reliable change estimates, criteria for change by reliable change estimates, and criteria for change by sample proportion on the Child SCAT5

	Test-Retest Difference Scores					Standard Errors			Criteria for Change: Reliable Change Estimates[a]				Criteria for Change: Sample Proportion[b]			
Child SCAT5 Component	Range	M	Md	SD	IQR	SEM_1	SEM_2	S_{diff}	70% CI	80% CI	90% CI	95% CI	≤20%	≤15%	≤10%	≤5%
Symptom																
Total Score	-21 to 19	0.0	0	6.5	6	4.7	4.7	6.6	± 7	± 8	± 11	± 13	+5	+ 6	+ 9	+ 12
Severity	-33 to 33	0.2	0	10.2	10	7.4	7.2	10.3	± 11	± 13	± 17	± 20	+ 7	+ 10	+ 12	+ 17
SAC-C																
Total Score	-6 to 11	0.7	1	2.5	3	1.8	1.6	2.4	± 2	± 3	± 4	± 5	- 2	- 3	- 3	- 4
Immediate Memory	-5 to 9	0.4	0	1.7	1	1.2	0.9	1.5	± 1	± 2	± 3	± 3	- 1	- 1	- 2	- 2
Digits Backwards	-3 to 3	0.3	0	1	1	0.7	0.7	1	± 1	± 1	± 2	± 2	- 1	- 1	- 1	- 1
Concentration	-3 to 3	0.3	0	1.1	1	0.7	0.7	1	± 1	± 1	± 2	± 2	- 1	- 1	- 1	- 1
Delayed Recall	-4 to 4	0.0	0	1.3	2	1	0.9	1.3	± 1	± 2	± 2	± 3	- 1	- 1	- 1	- 2
mBESS																
Total	-14 to 13	0.5	0	3.9	5	2.7	2.9	4	± 4	± 5	± 6	± 8	+ 4	+ 5	+ 6	+ 7
Tandem Leg	-4 to 7	0.2	0	1.7	2	1.1	1.4	1.7	± 2	± 2	± 3	± 3	+ 1	+ 2	+ 2	+ 3
Single Leg	-10 to 8	0.3	0	3	3	2.2	2.1	3	± 3	± 4	± 5	± 6	+ 2	+ 3	+ 4	+ 5

Note. The SEM S_{diff} and subsequent reliable change estimates were calculated with Spearman Rho (r_s) correlation coefficients. SEM = Standard Error Measure, CI = Confidence Interval, S_{diff} = Standard Error Difference.

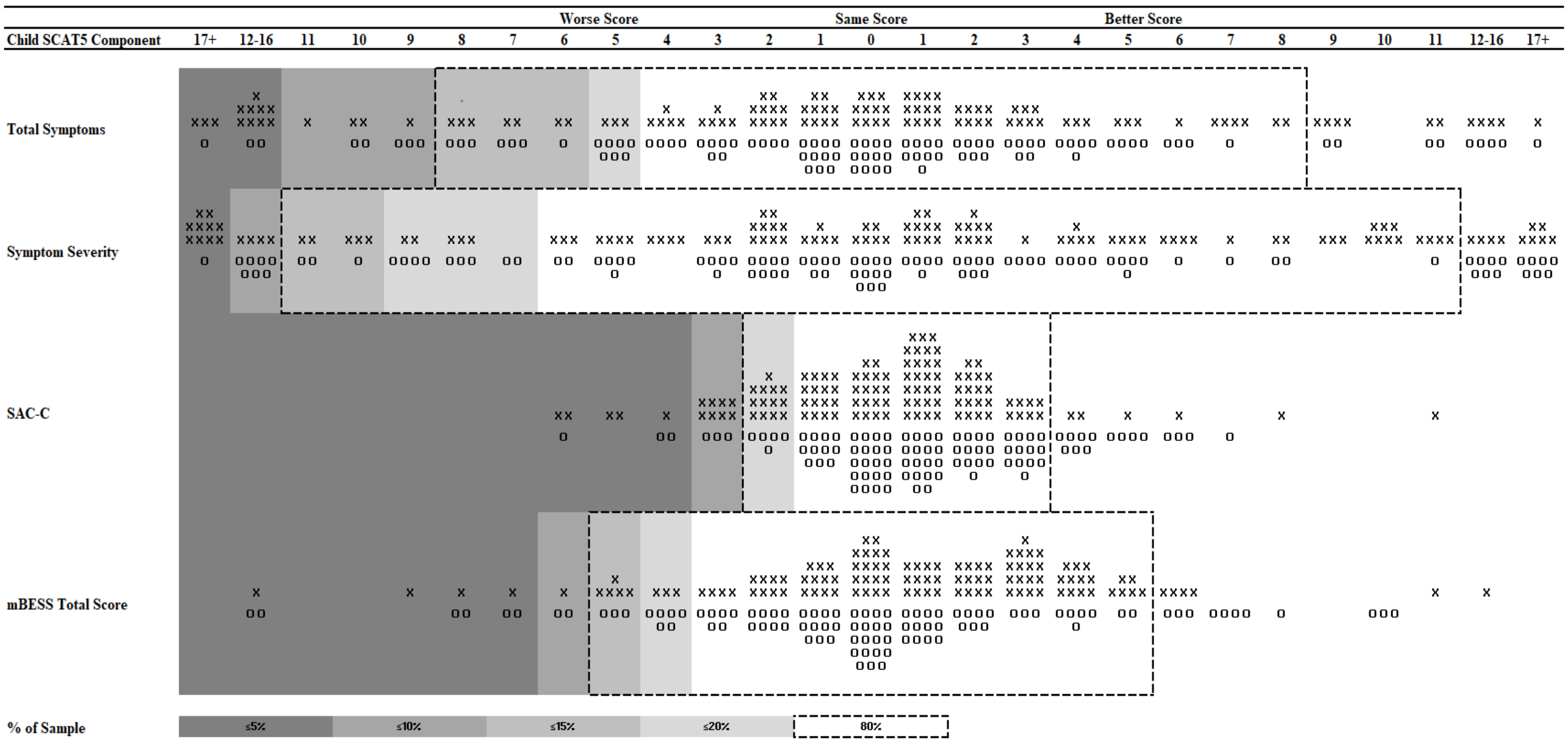

Figure 4. The natural distribution of test-retest difference scores on the Child SCAT5 (n=219).

Note. Participants who had the same score upon Retest scored 0, better scores are indicative of lesser symptom endorsement (Total Symptoms and Symptom Severity), better performance on SAC-C (e.g., scoring higher on Retest), and improved performance on mBESS assessments (e.g., scoring less errors upon Retest). The worst 5%, 10%, 15%, and 20% are highlighted in varying shades of grey, and midmost approximate 80% of participants are outlined in the dashed lines. Raters are denoted (X=Same, O=Different). Figure was designed by Hänninen et al.[29] SAC-C = Standardized Assessment of Concussion - Child Version. mBESS = Modified Balance Error Scoring System.

Change in Normative Classification. Regarding normative change, the majority of middle school student-athletes were classified as “Broadly Normal” at retest (see Table 17) and did not change in their normative classification upon retest assessments. This was true for both genders (girls and boys) and age groupings (ages 12 and 13 at retest). There were no statistically significant differences between the proportions of student-athletes who improved or declined in their normative Child SCAT5 classification at retest (Table 17 and Figures 5-6).

Table 17. Normative classifications for the sample at retest and percent of the sample that changed classification categories at retest.

Child SCAT5 Component	Broadly Normal	Above/Below Normal	Unusually High/Low	Extremely High/Low	No Change	Improved	Worsened	χ^2, p-value
Gender-Based Classifications								
Total Symptoms	77.3	14.7	5.3	2.7	70.7	12.7	16.7	0.82, p=0.37
Symptom Severity	78.7	12.7	4.7	4.0	68.7	15.3	16.0	0.02, p=0.99
SAC-C Total Score	84.0	9.3	5.3	1.3	70.0	17.3	12.7	1.09, p=0.30
Immediate Memory	86.0	10.0	2.7	1.3	76.7	12.7	10.7	0.26, p=0.61
Digits Backwards	88.7	10.0	1.3	----	84.0	8.7	7.3	0.17, p=0.68
Concentration	88.7	10.0	0.7	0.7	82.7	10.0	7.3	0.62, p=0.43
Delayed Recall	84.7	10.7	4.0	0.7	80.7	10.0	9.3	0.03, p=0.85
mBESS Total Score*	82.0	11.3	4.7	2.0	72.0	14.7	13.3	0.10, p=0.76
Age-Based Classifications								
Total Symptoms	76.7	12.0	8.7	2.7	67.5	14.0	18.7	1.00, p=0.32
Symptom Severity	76.0	15.3	6.0	2.7	65.3	17.3	17.3	0.01, p=1.00
SAC-C Total Score	82.0	11.3	5.3	1.3	70.0	16.7	13.3	0.56, p=0.46
Immediate Memory	86.0	10.0	2.0	2.0	76.0	12.7	11.3	0.11, p=0.74
Digits Backwards	85.3	13.3	1.3	----	78.0	12.7	9.3	0.76, p=0.38
Concentration	84.7	14.0	0.7	0.7	77.3	13.3	9.3	1.06, p=0.30
Delayed Recall	84.7	10.7	4.0	0.7	80.7	10.0	9.3	0.03, p=0.85
mBESS Total Scores*	86.7	8.0	3.3	2.0	77.3	13.3	9.3	1.06, p=0.30

Note. SAC-C = Standardized Assessment of Concussion - Child Version. mBESS = Modified Balance Error Scoring System. Normative classifications are derived from Kelshaw et al (P. M. Kelshaw, unpublished data, December 2019) from a sample of 1,000 middle school student-athletes that are also represented in the present study. “Broadly normal” scores fell within the 25th or 75th percentile ranks. The “below/above normal” scores were defined as close as possible to the 24th or 76th percentile ranks. The “unusually low/high” scores corresponded with the 10th and 90th percentile ranks. “Extremely low/high” corresponded with the 2nd and 98th percentile ranks. Labels for normative values were anchored by the direction of scores that indicate better performance.
*Normative ranks were not created for tandem or single leg stances, (P. M. Kelshaw, unpublished data, December 2019) thus they are not included in this table.

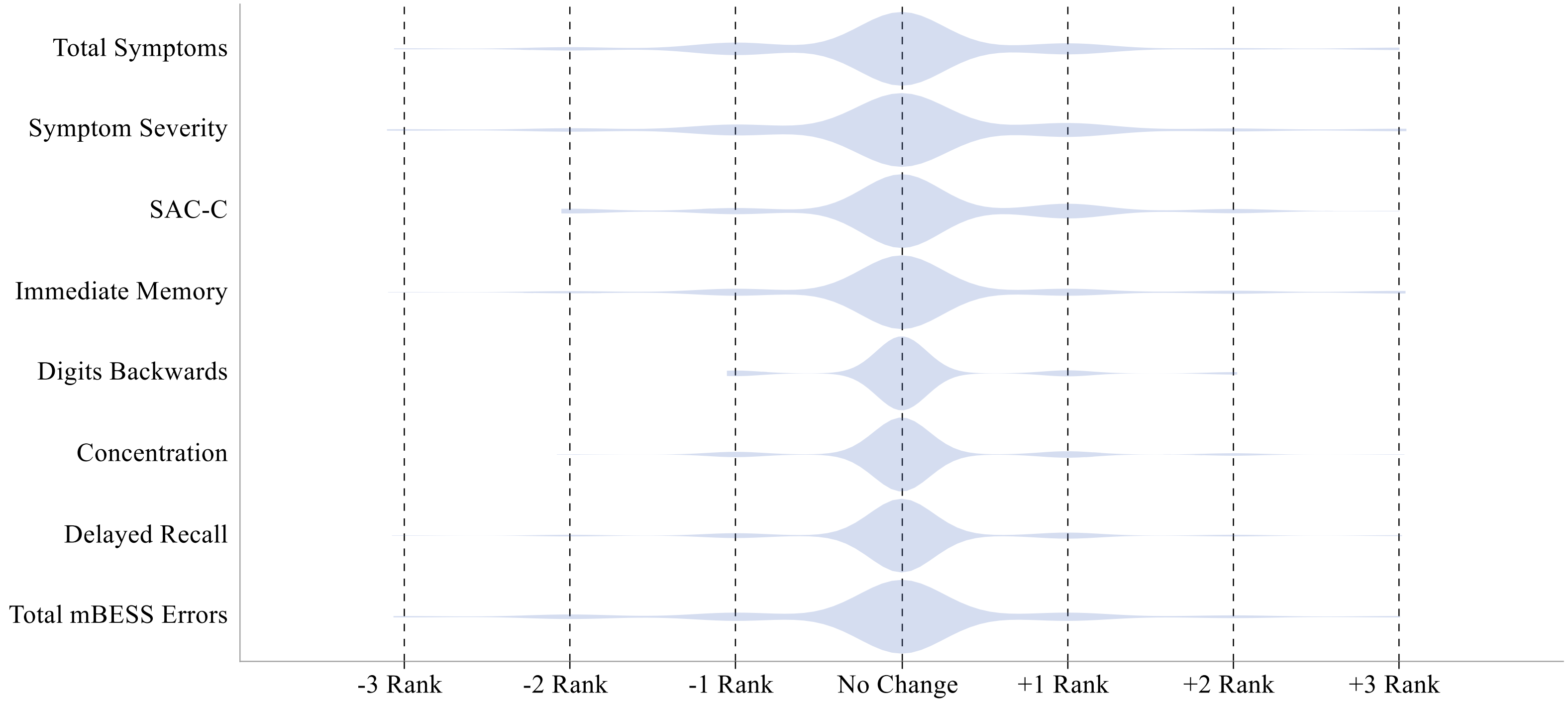

Figure 5. Distribution of group change in normative classifications by gender ranks at Retest Child SCAT5 baseline assessment (n=150).

Note. Normative rank changes are based upon the normative classifications created by Kelshaw et al (P. M. Kelshaw, unpublished data, December 2019) "No change" indicates that there was no change in the normative classification at Retest, "+1 Rank" indicates that the athlete improved by one ranking, "+2 Rank" indicates that the athlete improved by 2 rankings, etc. "-1 Rank" indicates that the athlete declined by 1 rank, "-2 Rank" indicates that the athlete declined by two normative ranks, etc. SAC-C = Standardized Assessment of Concussion - Child Version, mBESS = Modified Balance Error Scoring System.

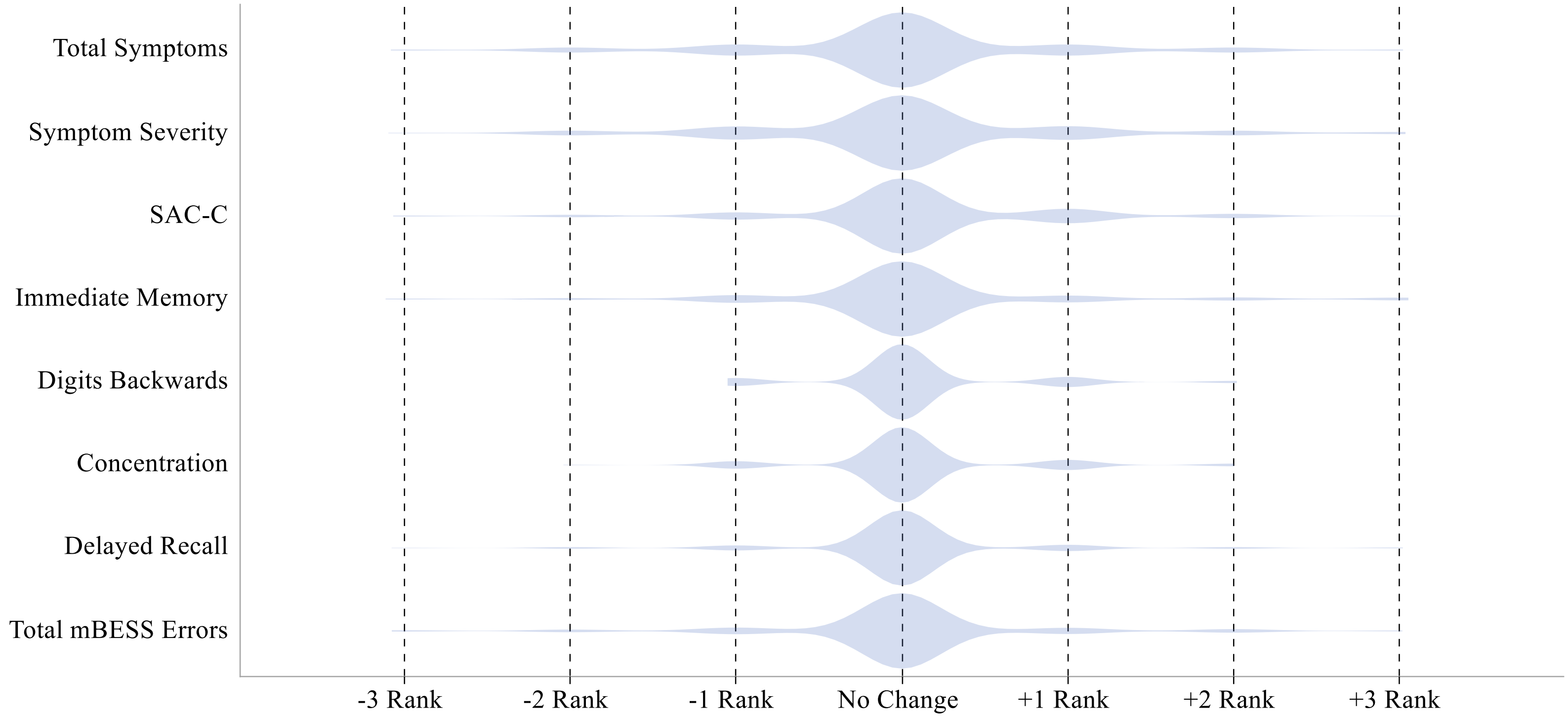

Figure 6. Distribution of group change in normative classifications by age ranks at Retest Child SCAT5 baseline assessment (n=150).

Note. Normative rank changes are based upon the normative classifications created by Kelshaw et al (P. M. Kelshaw, unpublished data, December 2019) "No change" indicates that there was no change in the normative classification at Retest, "+1 Rank" indicates that the athlete improved by one ranking, "+2 Rank" indicates that the athlete improved by 2 rankings, etc. "-1 Rank" indicates that the athlete declined by 1 rank, "-2 Rank" indicates that the athlete declined by two normative ranks, etc. SAC-C = Standardized Assessment of Concussion - Child Version, mBESS = Modified Balance Error Scoring System.

Discussion

This study is the first to report test-retest reliability estimates and reliable change values for serial baseline assessments of the Child SCAT5 among uninjured middle school student-athletes. The Child SCAT5 had poor temporal stability across the component scores over a one-year retest interval. Low reliability coefficients were observed for the full sample, those with no pre-existing health conditions, and for student-athletes having the same or a different rater at retest. However, scores obtained across the two assessments generally fell within the same interpretive normative ranges. Specifically, a majority of student-athletes (65.3%–84.0%) remained in the same normative classification upon retest assessments (see Table 17). Further, minimal change was observed at the group-level, when examining mean and median Child SCAT5 scores across test administrations (see Table 13). Collectively, it is likely that middle school student-athletes will perform similarly, relative to demographic-expectations (P. M. Kelshaw, unpublished data, December 2019), at their second assessment. This suggests that if practice effects and developmental effects are occurring, in addition to natural variation in test scores, when using the Child SCAT5 over a one-year retest interval, these effects might not significantly interfere with normative interpretation in children of this age (i.e., ages 11-12).

Prior studies have reported test-retest reliability for other assessment measures for sports-related concussion, such as the Child SCAT3,[85] SCAT3,[29] computerized test batteries,[92,173–176] SAC/SAC-C,[19,29,166,177] and mBESS.[19,29,166,177] However, limited information is available regarding test-retest reliability of pediatric concussion assessments,[85,178] and no prior study has investigated the reliability of the Child SCAT5. Within our cohort of middle school-age student-athletes, the Child SCAT5 had poor one-year test-retest reliability. These results are consistent with reliability estimates for the prior version of this instrument (i.e., Child SCAT3).[85]

Temporal stability remained low across subsamples of same or different raters across the assessments as well. Cognitive tests had the poorest reliability coefficients by the same rater (although this was likely due in part due to ceiling effects), while the mBESS had the poorest reliability by different raters. In addition, student-athletes with the same rater for both assessments had greater variability in scores (i.e., greater test-retest difference scores) for the mBESS than student-athletes having a different rater, although with small magnitude effects. Specifically, student-athletes with the same rater showed a greater improvement in scores than those with different raters. The reliability coefficients in the present study are modestly higher on the mBESS (although still generally low) than a previous study of the Child SCAT3 (Pearson r =.02),[85] despite differences in balance assessments on the Child SCAT3 versus Child SCAT5 (e.g., addition of single leg stance), differences in sample demographics (Nelson et al.: children ages 9-13, 84.2% male), varying retest interval (Nelson et al.: range 14-208 days), and statistical approaches (Pearson vs Spearman reliability coefficients). Further research is needed to investigate intra- and inter-rater reliability of the mBESS with children. Of note, for the present study, the student-athletes, sports, and testing environments did not change between the two assessments; the raters changed at five of the nine middle schools. Future research should further investigate the discrepancies of rater effects on the mBESS when used with children.

The distribution of Child SCAT5 test-retest difference scores (i.e., individual change) is illustrated in detail (see Figure 4), and may assist clinicians with recognizing and interpreting change upon a serial baseline assessment for middle school-age student-athletes. Based on the natural distribution of difference scores, we found that 20% or fewer participants showed the following worsening of performance on the Child SCAT5 retest scores: An increase of 5 or more total symptoms endorsed, an increase in 7 or more points on symptom severity score, a worsening of 2 or more points on the SAC-C total score, and an increase in 4 or more errors for total mBESS score. Further, clinicians should be aware that uninjured middle school student-athletes performed nearly perfectly on the double leg stance for the mBESS (99.5%) and days of the week backwards on the SAC-C (98.2%); errors on these components should be considered abnormal. It is important to note that the Child SCAT5 does not have a formal standard or threshold for interpreting change in scores in children. Interpretation of change requires clinicians to account for the full circumstances of the suspected injury, in addition to known psychometric properties of the test, such as temporal stability among uninjured athletes. It is important to appreciate that worsening by one or more normative classification ranges is uncommon (see Table 17), although if a child's initial score is very close to the cutoff between classifications, worsening would, of course, be statistically more likely for that child in the absence of injury. This may lend support to using both normative classifications and reliable change difference scores in clinical practice.

Limitations. This study has several limitations. Our sample represents middle school-age student-athletes (ages 11-12) and may not be generalizable to athletes outside of this age range. In addition, this study only included the upper bound of the Child SCAT5 age limit (i.e., ages 11-12) and did not include children ages 5-10 who might also be given the Child SCAT5. It is possible that older children may perform at the ceiling but younger children would have more variability in test performance. A strength of our study is that all testing administration and data collection processes were standardized and implemented within school-based practice settings. Of note, some participants were tested indoors (e.g., wrestling, basketball, and volleyball) and some were tested outdoors (e.g., soccer, football, baseball, and softball), which could contribute to reliability differences, particularly for the mBESS assessment. Further, the Child SCAT5 includes a parent-report symptom scale. However, we did not have consistent access to, or compliance from, parents. Future research should strive to replicate serial assessments of baseline concussion performance in consistent environments, and investigate the temporal stability of the Child SCAT5 across various time intervals.

Conclusions

Currently, there are no evidence-based guidelines for the interpretation of Child SCAT5 scores. Nor are there evidence-based recommendations regarding the frequency in which baseline Child SCAT5 assessments should be administered. Within our cohort of middle school-age student-athletes, the Child SCAT5 had poor one-year temporal stability. This makes comparisons of performances across serial administrations for clinical purposes challenging. However, we observed that middle school student-athletes were likely to score within the same normative classification range across serial baseline performances of the Child SCAT5. Collectively, our findings suggest that clinicians may benefit from referencing normative score ranges *and* individual comparisons to baseline scores when evaluating middle school aged student-athlete performance on the Child SCAT5 following a suspected injury. Specifically, clinicians can choose, based on their level of desired specificity, the cutoff scores they prefer for interpreting retest performance following a suspected injury (e.g., using the 15% or 20% cutoffs based on the natural distribution of difference scores). This information can be combined with considering a change in normative classification ranges. A worsening that was both uncommon (e.g., beyond the 15% cutoff) and a change in normative classification, for example, would be of clinical concern.

Chapter Five Study III – The Acute Presentation of Sports-Related Concussion Among Middle School Children During Sideline Assessment

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Abstract

Objectives: The Child Sport Concussion Assessment Tool 5th Edition (Child SCAT5) is designed to evaluate pediatric symptoms, cognition, and balance after a suspected concussion. The purpose of this study was to describe the ultra acute sideline Child SCAT5 component scores of concussed middle school children. Two different methods interpreting sideline SCAT5 scores are compared.

Design: A cross-sectional study was conducted from August 2017 to December 2019 as part of George Mason University's Advancing Healthcare Initiatives for Underserved Students (ACHIEVES) Project. Students were recruited from nine middle schools in one large public school district in Virginia, USA. Forty-two middle school age children (ages 11-13, M=12.5, SD=0.7; 38.1% girls, 61.9% boys) were assessed and diagnosed with a sports-related concussion by certified athletic trainers on the sideline with the Child SCAT5. All of these children also had completed pre-participation baseline Child SCAT5 evaluations.

Results: Acutely following concussion, children endorsed more total symptoms ($z=-2.72$, $P=.01$, $r=-.43$) and greater symptom severity ($z=-2.49$, $P=.01$, $r=-0.39$) compared to their own baseline. Further, total mBESS ($z=-3.68$, $p<0.01$, $r=-.57$), tandem stance ($z=-3.42$, $p<0.01$, $r=-.53$), and single leg stance ($z=-3.32$, $p<0.01$, $r=-.51$) were statistically significantly worse on sideline assessments compared to baseline. All Child SCAT5 component scores were statistically significantly worse during sideline assessments compared to normative reference values, although with small effects (r's = -.14 to -.06). A majority of the sample were detected as impaired upon applying the normative reference values (69.0%), reliable change estimates (69.0%), and when applying both methods (81.0%).

Conclusions: Acutely concussed children obtained worse scores on the Child SCAT5 compared to their own personal baseline scores, with medium effect sizes. When using normative sample comparisons, there were small differences noted in this concussed sample. We provide preliminary evidence to support the application of normative reference classifications and/or reliable change estimates for interpreting post-injury Child SCAT5 component scores.

Introduction

Currently, all 50 states and the District of Columbia have enacted legislation mandating the immediate removal of child athletes recognized as sustaining a concussion from sport.[62,63,179,180] However, concussion recognition and diagnosis is challenging due to diverse clinical presentations. The effects of concussions are commonly assessed using tests designed to measure subjectively-experienced symptoms, cognitive functioning, and static balance and postural stability.[12,72,181] For children, the recommended assessment tool for immediate on-field assessment of a sports-related concussion is the Child Sport Concussion Assessment Tool 5th Edition (Child SCAT5).[12,182] To date, empirical guidance for interpreting Child SCAT5 performance acutely following concussion does not exist. Clinicians working with children thus rely mostly on subjective clinical interpretations of Child SCAT5 scores to inform their clinical decision-making.

The two potential methods for interpreting Child SCAT5 performance following concussion are to (i) compare a child's performance to his or her own personal, pre-injury baseline or, (ii) compare obtained results to normative reference values.[28] However, individual baseline-to-post injury comparisons are limited by the Child SCAT5's low one year test-retest reliability (P. M. Kelshaw, unpublished data, February 2020). In addition, normative reference values are often limited by relatively small samples or samples that are not representative of the individual being assessed. In 2019, we generated Child SCAT5 normative reference values for children, stratified by unique demographic characteristics that allow clinicians to select normative reference groupings that match patients being evaluated as closely as possible (P. M. Kelshaw, unpublished data, December 2019). Further, in 2020 we generated reliable change estimates to supplement clinical interpretation of change during serial assessments of the Child SCAT5 (P. M. Kelshaw, unpublished data, February 2020). However, neither of these clinical interpretation recommendations have been applied to a sample of concussed children.

In an effort to improve the methodology for assessing concussion in children ages 11-13, we sought to describe ultra acute (i.e., “sideline”) Child SCAT5 component scores, and explore changes that may be present acutely for children with concussion via the following clinical interpretation methods: (i) a comparison of sideline Child SCAT5 component scores to individual baselines, (ii) an examination of the proportion of children that reliably change in Child SCAT5 sideline component scores, and (iii) a comparison of sideline Child SCAT5 component scores to normative reference values.

Methods

Participants. A total of 72 children were assessed with the Child SCAT5 following a concussion within 24 hours to 1 week following injury (ages 11-13, M=12.3, SD=0.7; 36% girls, 64% boys) by a certified athletic trainer between 2017-2019. Of these, 53 children (ages 11-13, M=12.3, SD=0.7; 41% girls, 59% boys) were assessed with the Child SCAT5 immediately on the sideline and diagnosed with a sports-related concussion by a certified athletic trainer. Children included in this study participated in football (n=14, 26.4%), wrestling (n=11, 20.8%), volleyball (n=8, 15.1%), girls’ soccer (n=6, 11.3%), boys’ basketball (n=3, 5.7%), girls’ basketball (n=3, 5.7%), cheerleading (3, 5.7%), boys’ soccer (n=3, 5.7%), and track and field (n=2, 3.8%). Of the total participants, 42 (ages 11-13, M=12.5, SD=0.7; 38.1% girls, 61.9% boys) also completed pre-injury, baseline Child SCAT5 assessments. Baseline to sideline Child SCAT5 evaluation intervals varied from 1 to 139 days (M=27.1, Md=20.5, SD=28.3). The George Mason University Institutional Review Board approved the construction of the deidentified database for retrospective research purposes and waived assent and consent (See Appendix A).

Instrument. The Child SCAT5 is designed for medical professionals as a standardized assessment tool in the evaluation (both baseline and post injury) of concussions in children. The Child SCAT5 is comprised of (i) total number of symptoms (range: 0-21) and (ii) severity of symptoms endorsed by the student (range: 0-63), (iii) Standard Assessment of Concussion – Child Version total score (SAC-C; range: 0-26), which includes (iv) immediate memory (range: 0-15), (v) concentration (range: 0-6), (vi) digits backwards (range: 0-5) and (vii) delayed recall (range 0-5), as well as balance scores from the Modified Balance Error Scoring System (mBESS) (viii) total errors (range:0=30), (ix) tandem stance (range: 0-10), and (x) single leg stance range (0-10). Higher scores on cognitive measures (e.g., SAC-C total, immediate memory, concentration, and delayed recall) indicate better functioning and higher scores on symptom reporting and balance errors indicate worse functioning.

Testing Procedures. George Mason University's Advancing Healthcare Initiatives for Underserved Students (ACHIEVES) Project provided embedded certified athletic trainers (ATs) in nine middle schools within a large socioculturally diverse school district[61] in Virginia, USA. As part of pre-participation assessments certified athletic trainers (ATs) administered the Child SCAT5 to students during the first two weeks of sports participation (i.e., “baseline), consistent with prior methods (P. M. Kelshaw, unpublished data, December 2019). Children that participated in cheerleading or track and field did not complete baseline assessments because these sports have a lower risk of concussion incidence.[183] All ATs attended training sessions on appropriate administration of the Child SCAT5 for baseline and post-injury evaluations. Baseline assessments were conducted in a minimally distracting environment and when children were in a rested state. Children self-reported their demographic characteristics (e.g., gender and age) as well as their health history as collected on the Child SCAT5 (e.g., self-reported history of concussion, prior hospitalization from a head injury, headache disorder or migraines, LD/dyslexia, ADHD, or depression, anxiety, or other psychiatric disorders). Upon suspicion of a concussion, ATs utilized the Child SCAT5 to assess the child. Ultra acute assessments occurred on the sidelines of the practice or competition. Only sideline Child SCAT5 assessments that resulted in a diagnosed sports-related concussion by the AT were included in this study.

Analyses

Descriptive statistics were used to summarize demographic information for baseline and sideline Child SCAT5 scores. Participants were stratified into the following subsamples: (i) The full sample of students diagnosed with a concussion on the sideline (n=53), and (ii) students who completed baseline and sideline assessments (n=42). Normality tests indicated that all dependent variables (i.e., the Child SCAT5 component scores) were non-normally distributed (Shapiro-Wilk, P’s<.05). Thus, nonparametric analyses were used. All statistical analyses were performed with SPSS (v. 23, IBM Corp., NY, USA). Alpha was set a priori at $p<0.05$. All figures were generated with RStudio (RStudio, Inc., Boston, MA, USA).

Baseline and Normative Comparisons. Wilcoxon Signed-Rank tests were used to assess for significant differences between baseline and sideline assessments (n=42) for all Child SCAT5 components. Raincloud plots[171,172] were created to visually display the distribution of raw scores on baseline versus sideline (n=42) for all Child SCAT5 components. Sideline scores were compared to normative scores generated from a large sample of uninjured middle school age children (P. M. Kelshaw, unpublished data, December 2019). Mann-Whitney U analyses were used to assess for differences between the sample of normative Child SCAT5 scores and the sample of sideline scores. Proportions of children per Child SCAT5 component were stratified by those who fell within the same normative category, by those that improved, and by those who declined in baseline normative categories at sideline assessments. A Chi Square test was used to compare the proportion of athletes that either improved or declined in normative categories at sideline assessments.[170] The z values from the Wilcoxon Signed-Rank and Mann-Whitney U tests were used to calculate a nonparametric effect size[157] $(r = \frac{z}{\sqrt{N}})$ and were interpreted according to conventional guidelines (i.e., r=0.1, small; r=0.3, medium; r=0.5, large).[158]

Reliable & Uncommon Change Comparisons. A test-retest sample of 219 middle school age children were baseline tested twice during the 2017-18 and 2018-19 academic years, and are described in detail elsewhere (P. M. Kelshaw, unpublished data, February 2020). The two-year test-retest change score, hereafter referred to as “test-retest difference scores" were calculated by subtracting Year 1 baseline scores from Year 2 baseline scores, in order to illustrate the normal test-retest variability among uninjured middle school athletes (P. M. Kelshaw, unpublished data, February 2020). We selected the 20th percentile as a cutoff score for "reliable change" from reliable change estimates derived from the natural distribution of the test-retest difference scores. The reliable change cutoffs corresponded with the following: total symptom score ≥5, symptom severity ≥7, SAC-C total score ≤-2, immediate memory ≤-1, digits backwards ≤-1, concentration ≤-1, delayed recall ≤-1, total mBESS score ≥4, tandem leg ≥1, and single leg ≥2. Further, we selected the 15th percentile as "uncommon change." Uncommon change cutoffs corresponded with the following: total symptom score ≥6, symptom severity ≥10, SAC-C total score ≤-3, immediate memory ≤-1, digits backwards ≤-1, concentration ≤-1, delayed recall ≤-1, total mBESS score ≥5, tandem leg ≥2, and single leg ≥3.

To compare the variability of scores among concussed athletes, to the test-retest difference scores among healthy athletes, we calculated individual baseline to sideline change scores, hereafter referred to as "baseline-sideline difference scores." These scores were calculated by subtracting the individual baseline scores of the concussed sample from their post-injury sideline scores on the Child SCAT5, consistent with prior methods.[93,124] The proportions of children that fell beyond the reliable change cutoffs, and uncommon change cutoffs, following a concussion (via the baseline-sideline difference scores) were reported.

Results

Sample demographics are summarized in Table 18. Sports-related concussions were sustained more often during practices (n=37, 69.8%) than competitions (n=16, 30.2%). Acute, "observable signs" of concussion, as documented on the Child SCAT5, were observed for 9 participants (17.0%). The observed signs of concussion for these 9 participants are provided in Table 19. Moreover, "red flags" as documented on the Child SCAT5, were observed for 6 participants (11.3%). The "red flags" documented for these 6 participants are provided in Table 20.

Table 18. Demographic and self-reported health history characteristics for the concussed sample of middle school children ages 11-13.

	Sideline Only n = 53	Baseline & Sideline n = 42
Boys (n, %)	31 (58.5)	26 (61.9)
Girls (n, %)	22 (41.5)	16 (38.1)
Age M (SD)	12.4 (0.7)	12.5 (0.7)
Grade M (SD)	7.1 (0.7)	7.2 (0.6)
Number of prior concussions M (SD)	1.2 (0.8)	1.2 (0.8)
Zero prior concussions (n, %)	2 (3.7)	2 (4.8)
1 prior concussion (n, %)	13 (24.5)	13 (31.0)
2 or more prior concussions (n, %)	3 (5.6)	3 (7.2)
Hospitalized for head injury (n, %)	4 (7.5)	4 (9.5)
Headache disorder/migraines (n, %)	3 (5.6)	3 (7.1)
Learning disability/dyslexia (n, %)	1 (1.9)	1 (2.4)
ADHD (n, %)	2 (3.7)	2 (4.8)
Psychiatric disorder (n, %)	1 (1.9)	1 (2.4)

Note. ADHD = Attention-Deficit/Hyperactivity Disorder

Table 19. Documented observable signs of concussion upon sideline assessments.

Subject	Lying motionless on the playing surface	Balance / gait difficulties / motor incoordination: stumbling, slow / labored movements	Disorientation or confusion, or an inability to respond appropriately to questions	Blank or vacant look	Facial injury after head trauma
1	No	Yes	No	Yes	No
2	No	Yes	No	No	Yes
3	No	No	No	Yes	No
4	No	Yes	No	No	No
5	No	Yes	No	No	No
6	No	No	No	Yes	No
7	No	Yes	No	Yes	No
8	No	Yes	No	Yes	No
9	No	No	No	Yes	No

Table 20. Documented “red flags” upon sideline assessments.

Subject	Neck pain or tenderness	Double vision	Weakness or tingling/ burning in arms or legs	Severe or increasing headache	Seizure or convulsion	Loss of consciousness	Deteriorating conscious state	Vomiting	Increasingly restless, agitated or combative
1	Yes	No	No	Yes	No	No	No	No	No
2	Yes	Yes	No	Yes	No	No	No	No	No
3	Yes	No	No	Yes	No	No	No	No	No
4	Yes	No	No	Yes	No	No	No	No	No
5	No	Yes	No	Yes	No	No	No	No	No
6	No	No	No	Yes	No	No	No	Yes	Yes

All 53 children endorsed having symptoms during the sideline assessment. Of the full 53 participants that were acutely assessed on the sidelines, 3 (5.7%) did not complete all SAC-C components. Specifically, one participant did not complete any SAC-C components, and two participants did not complete the delayed recall component. For these individuals, a total SAC-C score was not calculated, however individual component scores of the SAC-C that were completed (e.g., immediate memory, concentration, etc.) were included. Further, one participant did not complete any mBESS measures, as such there were no scores to include in the analyses for this individual. In addition, 5 (9.4%) participants were unable to maintain any stance beyond 5 seconds. For these 5 participants, each stance was assigned a score of 10 per stance, for a maximum of 30 mBESS total errors, as required by the mBESS scoring instructions.[12] Further, 3 (5.7%) participants were unable to complete the tandem and single leg stances beyond 5 seconds and were assigned a score of 10 per stance. An additional 9 (17.0%) participants were unable to complete the single leg stance and were assigned the maximum error score of 10 for this stance.

Of the sample of 42 participants that completed both baseline and sideline assessments, one did not complete the delayed recall assessment. Therefore, this individual did not receive a total SAC-C score. All participants that completed both a baseline and sideline assessment received scores for the mBESS. The same methods of scoring were applied when participants were unable to complete the stances beyond 5 seconds. Specifically, 5 (11.9%), 2 (4.8%), and 8 (19.0%) participants were assigned maximum error scores for all three stances, tandem and single leg stances, and single leg stance, respectively. Descriptive statistics for ultra-acute sideline Child SCAT5 scores are provided in Table 21.

Table 21. Descriptive statistics for ultra-acute sideline Child SCAT5 scores.

Child SCAT5 Component	n	Range	M	Md	SD	IQR
Symptom						
Total Score	53	1-21	10.3	10	6.0	5-16
Severity	53	1-47	17.4	15	12.8	6-29
SAC-C						
Total Score	50	5-25	19.9	21	4.0	19-23
Immediate Memory	51	2-15	13.0	14	2.5	12-15
Digits Backwards	51	1-5	2.7	3	0.9	2-3
Concentration	51	1-6	3.7	4	1.0	3-4
Delayed Recall	50	0-5	3.2	4	1.5	2-4
mBESS						
Total	52	0-30	10.7	9	8.3	4-13
Tandem Leg	52	0-10	3.2	2	3.4	1-4
Single Leg	52	0-10	6.3	7	3.4	3-10

Note. SAC-C = Standardized Assessment of Concussion - Child Version, mBESS = Modified Balance Error Scoring System, M = Mean, Md = Median, SD = Standard Deviation, IQR = Interquartile Range.

Sideline and Baseline Comparisons. Sideline total symptoms and symptom severity were significantly higher than baseline (z=-2.72, p=0.01, r=-.43 and z=-2.49, p=0.01, r=-0.39 respectively), with medium effect sizes. More balance errors were committed on sideline assessments than baseline [Total mBESS score (z=-3.68, p<0.01, r=-.57), tandem stance (z=-3.42, p<0.01, r=-.53), and single leg stance (z=-3.32, p<0.01, r=-.51)], with large effect sizes. There were no statistically significant differences on any Child SCAT5 cognitive scores (e.g. SAC-C, immediate memory, digits backwards, concentration, and delayed recall, p’s>.05) between baseline and sideline assessments. Figures 7-9 display the raw baseline and day-of-injury Child SCAT5 scores.

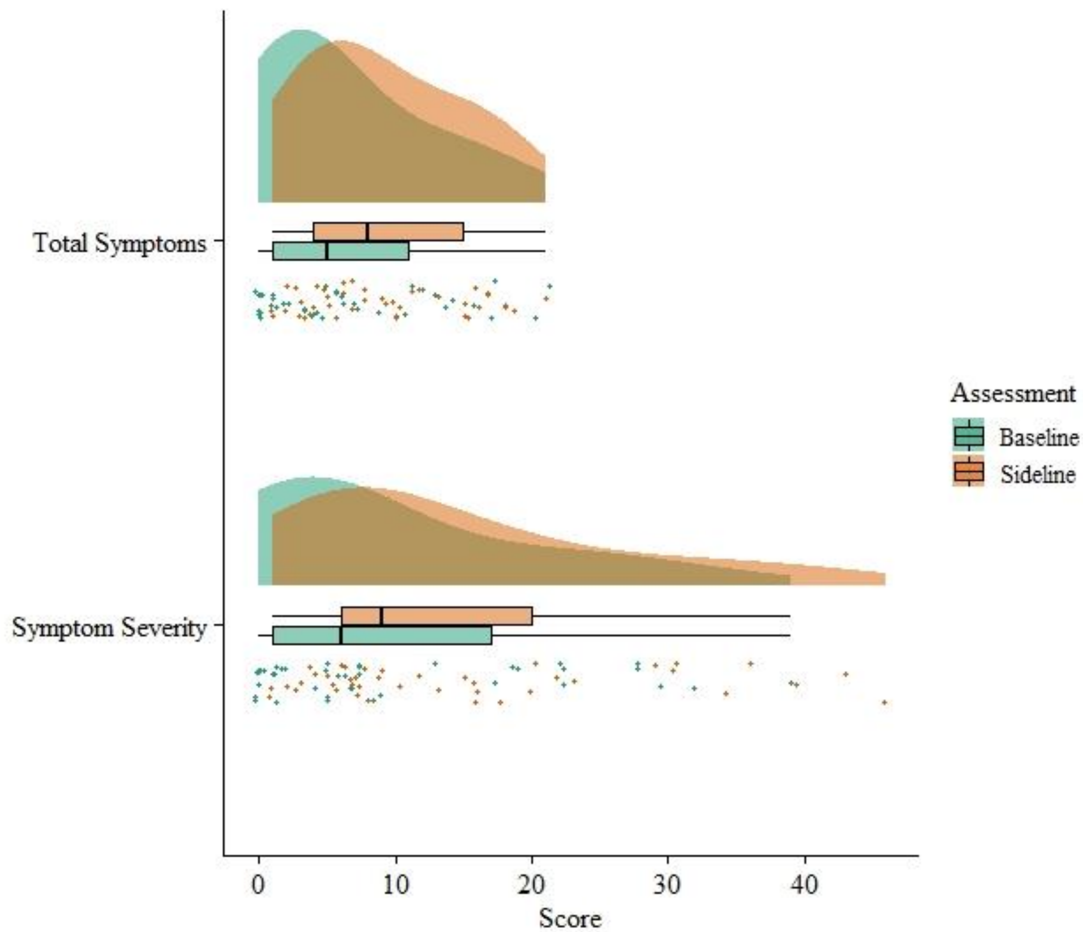

Figure 7. Raincloud plot of raw Child SCAT5 total symptom and symptom severity scores at baseline and sideline assessments.

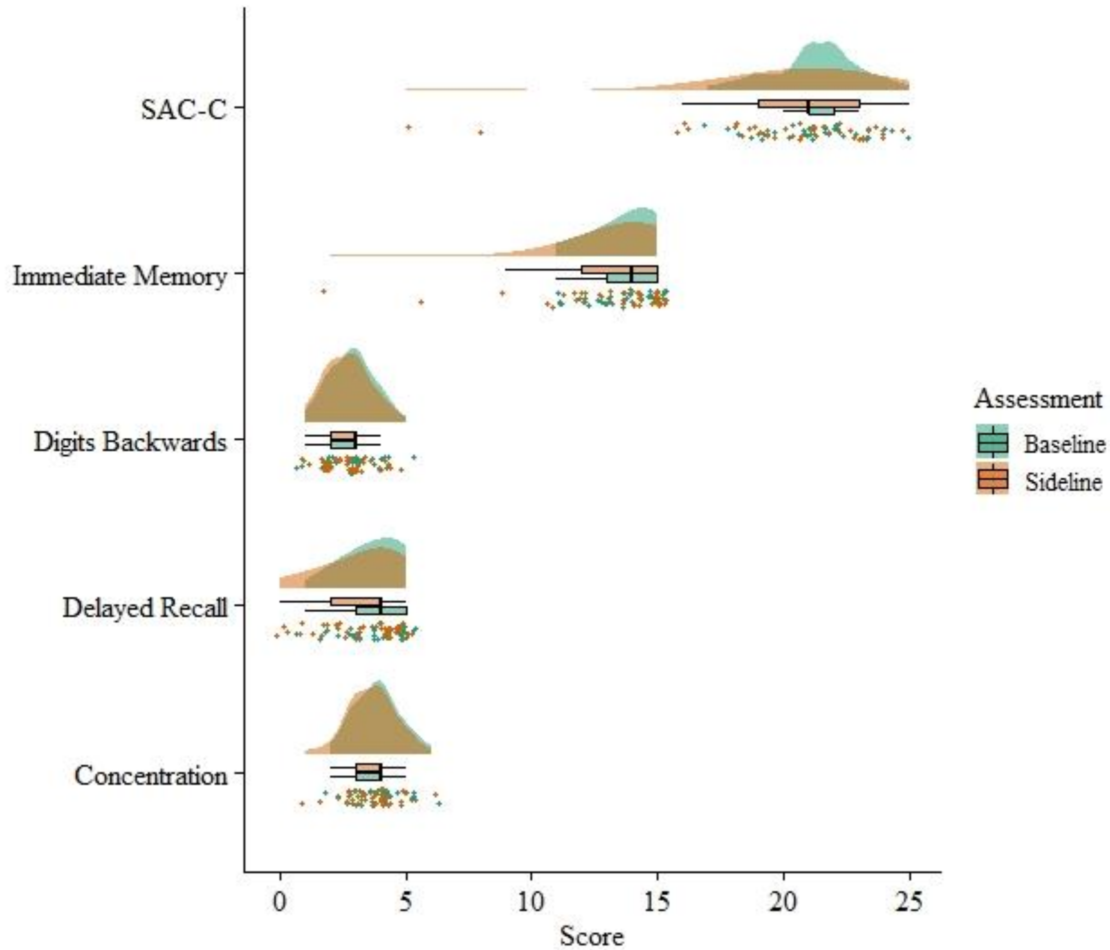

Figure 8. Raincloud plot of raw Child SCAT5 cognitive scores at baseline and sideline assessments.

Note. SAC-C = Standardized Assessment of Concussion - Child Version.

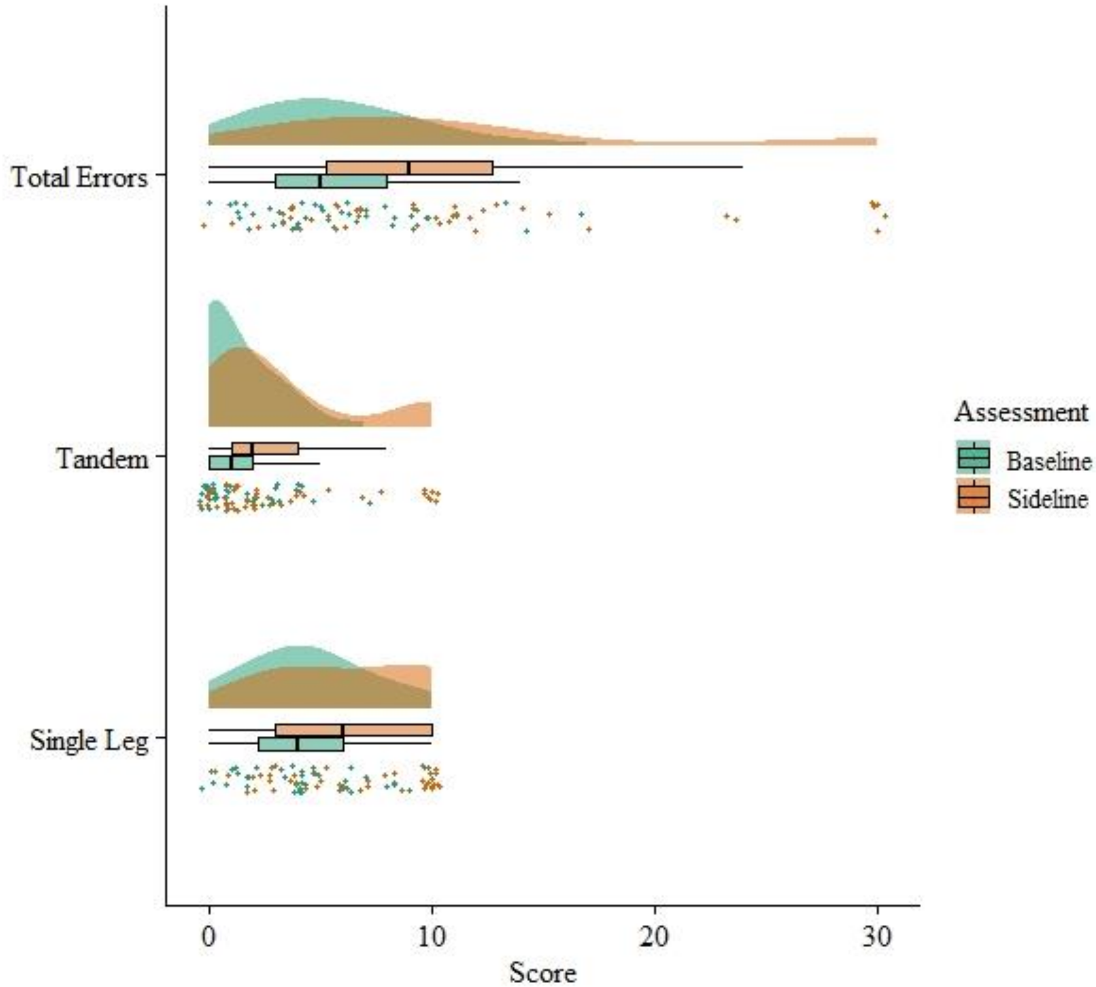

Figure 9. Raincloud Plot of raw Child SCAT5 balance scores at baseline and sideline assessments.

Note. mBESS = Modified Balance Error Scoring System.

On acute sideline assessments the most commonly endorsed symptoms were: “I have headaches” (100%), “I feel dizzy” (72.1%), and “I forget things” (58.8%). In contrast, at baseline, the most commonly endorsed symptoms were: “I get distracted easily” (48.8%), “I get tired a lot” (44.2%), “I have headaches” (41.9%), and “I forget things” (41.9%). Symptoms that are related to perceived vestibular/physical functioning domains (e.g., “I feel dizzy,” “things are blurry when I look at them,” and “I feel sick to my stomach”) are more likely to be endorsed upon sideline assessments than baseline. Symptoms that are related to perceived cognitive functioning (e.g., “I have trouble paying attention,” “I get distracted easily,” and “I have a hard time concentrating”) were endorsed nearly equally between baseline and sideline assessments. Other symptoms such as “I daydream too much”, “I have problems finishing things,” I have trouble figuring things out,” and “It’s hard for me to learn new things” were nearly equally endorsed at baseline and sideline. As such, these specific symptoms may be difficult for a child to interpret acutely following concussion. Symptom severity endorsement at baseline and during day-of-injury assessments are summarized in Table 22 and Figures 10-11.

Table 22. Symptom severity endorsement on the Child SCAT5 by proportion of children at baseline and sideline assessments (n=42).

Child SCAT5 Symptoms	Not at all/ Never		A little/ Rarely		Somewhat/ Sometimes		A lot/ Often	
	Baseline (%)	Sideline (%)	Baseline (%)	Sideline (%)	Baseline (%)	Sideline (%)	Baseline (%)	Sideline (%)
I have headaches	56.1	0.0	24.4	31.7	14.6	39.0	4.9	29.3
I feel dizzy	80.5	34.1	17.1	31.7	2.4	26.8	0.0	7.3
I feel like the room is spinning	90.2	58.5	9.8	26.8	0.0	7.3	0.0	7.3
I feel like I'm going to faint	92.7	68.3	4.9	24.4	2.4	7.3	0.0	0.0
Things are blurry when I look at them	80.5	61.0	9.8	24.4	4.9	9.8	4.9	4.9
I see double	85.4	80.5	12.2	12.2	2.4	2.4	0.0	4.9
I feel sick to my stomach	73.2	61.0	19.5	26.8	4.9	12.2	2.4	0.0
My neck hurts	80.5	58.5	19.5	29.3	0.0	7.3	0.0	2.4
I get tired a lot	53.7	48.8	34.1	26.8	9.8	17.1	2.4	7.3
I get tired easily	58.5	53.7	14.6	22.0	19.5	19.5	7.3	4.9
I have trouble paying attention	56.1	58.5	19.5	19.5	9.8	12.2	14.6	9.8
I get distracted easily	48.8	58.5	24.4	17.1	17.1	12.2	9.8	12.2
I have a hard time concentrating	65.9	58.5	17.1	22.0	9.8	9.8	7.3	9.8
I have problems remembering what people tell me	63.4	48.8	24.4	29.3	4.9	12.2	7.3	9.8
I have problems following directions	73.2	73.2	17.1	9.8	9.8	9.8	0.0	7.3
I daydream too much	65.9	68.3	19.5	12.2	9.8	12.2	4.9	7.3
I get confused	61.0	58.5	19.5	24.4	17.1	7.3	2.4	9.8
I forget things	56.1	46.3	19.5	36.6	22	12.2	2.4	4.9
I have problems finishing things	82.9	63.4	14.6	17.1	2.4	17.1	0.0	2.4
I have trouble figuring things out	68.3	63.4	24.4	22.0	4.9	12.2	2.4	2.4
It's hard for me to learn new things	75.6	70.7	14.6	14.6	7.3	9.8	2.4	4.8

Note. Students self-report their symptom endorsement by the corresponding severity category as noted on the Child SCAT5.[12,182]

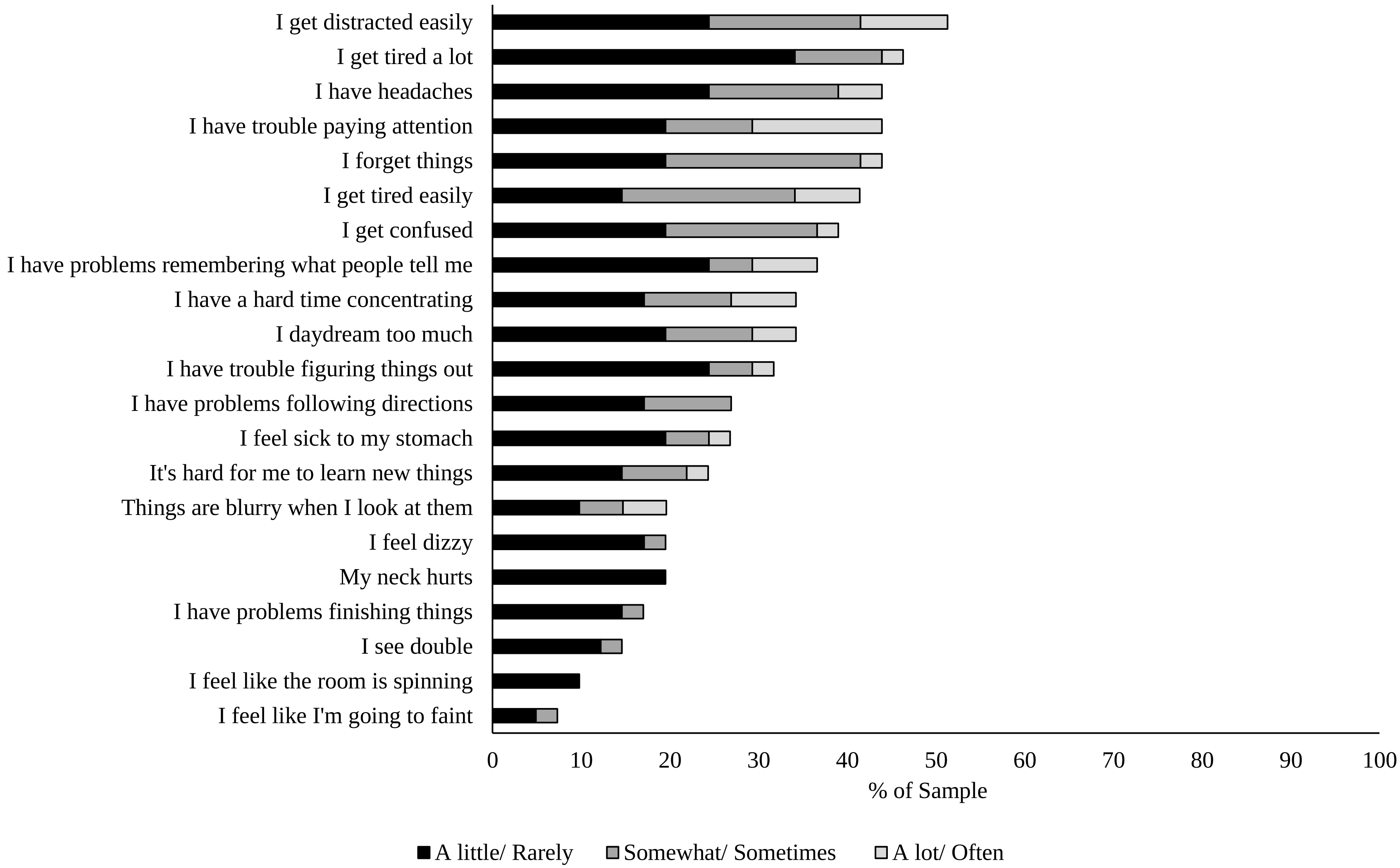

Figure 10. Baseline Child SCAT5 symptom severity endorsement (n=42).

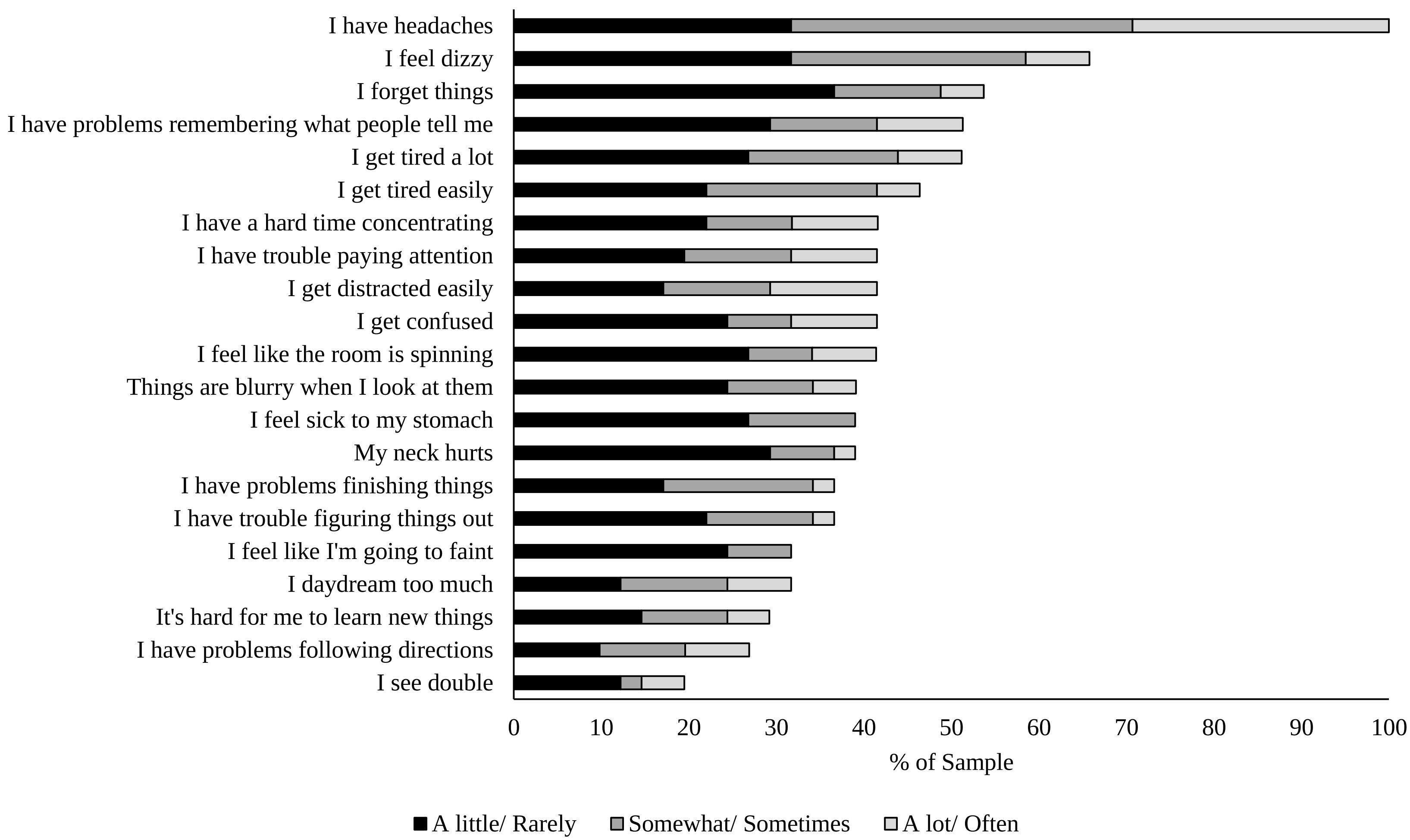

Figure 11. Day-of-injury Child SCAT5 symptom endorsement (n=42).

Symptom Algorithm for Sideline Assessment. The Child SCAT5 symptom questionnaire is not well designed for sideline evaluation of symptoms because many of the symptoms are worded to reflect the child's experience during daily life, and the wording does not relate well to acute symptoms. We selected 7 symptoms based on their frequencies of endorsement at baseline and on the sideline, their clinical content, and their wording on the questionnaire (i.e., headaches, dizzy, room spinning, feeling faint, blurry vision, feeling sick, and feeling tired). We created 3 scores for those 7 symptoms: (i) total number of symptoms endorsed, (ii) total symptom severity, and (iii) a 7-symptom algorithm. The algorithm was as follows: sum the number of symptoms, out of 7, reported in the following ranges: headaches (somewhat or greater), dizzy (somewhat or greater), room is spinning (somewhat or greater), feeling faint (a little or greater), blurry vision (a little or greater), feeling sick (somewhat or greater), and tired a lot (somewhat or greater). Descriptive statistics of the symptom algorithm are presented in Table 23. Sideline total of the 7 symptoms and total symptom severity for the 7 symptoms were significantly higher than baseline ($z=-4.17$, $p<0.01$, $r= 0.64$ and $z=-4.41$, $p<0.01$, $r=0.68$, respectively), with large effect sizes. The 7-symptom algorithm score was significantly higher post-injury compared to baseline ($z=-4.08$, $p<0.01$, $r=0.63$, with a similar large effect size).

Table 23. Descriptive statistics for the symptom algorithm for sideline assessments.

	Pre-Injury Baseline Assessment					Post-Injury Sideline Assessment				
	M	Md	SD	IQR	Range	M	Md	SD	IQR	Range
Total of 7 Symptoms	1.7	1.0	2.0	0-3	0-7	3.6	4.0	2.0	2-5	1-7
Total Severity (7 symptoms)	2.4	1.0	2.9	0-4	0-12	5.9	5.0	4.1	3-9	1-17
7-Symptom Algorithm	0.6	0.0	1.1	0-1	0-5	2.0	1.5	1.8	1-3	0-7

Note. M = Mean, Md = Median, SD = Standard Deviation, IQR = Interquartile Range.

Baseline-Sideline Difference Scores and Reliable Change Comparisons. Pre-season and post-injury scores for each child are presented in Table 24. The proportions of students' post-injury scores that are considered reliably worse compared to their preseason scores are summarized in Table 25. A greater number of participants had reliably worse scores on cognitive testing and balance testing than on symptom ratings. Most of the injured children obtained at least one reliably worse score, compared to their pre-injury baseline, on the symptom scale (number or severity), SAC-C total, or mBESS (i.e., 30/42; 71.4%).

Table 24. Baseline and sideline scores for all participants and corresponding reliable changes.

	Pre-Injury Baseline Child SCAT5 Scores										Post-Injury Sideline Child SCAT5 Scores									
	Symptom		SAC-C					mBESS			Symptom		SAC-C					mBESS		
Subject	Total	Severity	Total	IM	DB	Con	DR	Total	TL	SL	Total	Severity	Total	IM	DB	Con	DR	Total	TL	SL
1	4	7	23	15	2	3	5	8	4	4	9*	12	8*	6*	1*	1*	1*	30*	10*	10*
2	5	7	21	14	2	3	4	1	1	0	10*	16*	19*	11*	4	5	3*	2	0	2*
3	1	1	19	11	3	4	4	5	0	5	15*	36*	5*	2*	2*	3*	0*	11*	1*	10*
4	1	1	24	15	5	6	3	1	0	1	2	2	21*	15	2*	3*	3	0	0	0
5	6	6	21	15	4	5	1	4	2	2	3	3	25	15	5	6	4	7	2	5*
6	0	0	22	13	3	4	5	9	4	5	3	4	19*	12*	3	4	3*	6	3	3
7	1	1	22	14	2	3	5	7	3	4	7*	7	20*	13*	1*	2*	5	5	1	4
8	17	29	22	14	3	4	4	6	0	6	17	20	21	13*	3	4	4	6	4*	2
9	15	25	18	15	2	3	5	11	4	7	10	17	20	15	2	3	2*	13	3	10*
10	11	22	21	15	3	4	2	0	0	0	21*	46*	16*	11*	2*	3*	2	30*	10*	10*
11	9	13	22	14	3	4	4	4	0	4	10	16	23	14	4	5	4	17*	7*	8*
12	11	22	21	15	3	4	2	1	0	1	10	13	23	14*	4	5	4	9*	2*	7*
13	14	22	21	14	2	3	4	8	2	6	16	30*	19*	12*	3	4	3*	30*	10*	10*
14	4	5	20	12	2	3	5	4	0	4	8	10	21	15	3	4	2*	7	1*	6*
15	17	28	19	13	2	3	3	14	5	9	18	34	---	13	1*	2*	---	30*	10*	10
16	6	7	22	14	3	4	4	8	2	6	5	6	16*	9*	2*	3*	4	6	2	4
17	16	39	21	12	3	4	5	17	7	10	12	29	20	12	2*	3*	5	12	2	10
18	12	19	22	12	4	5	5	13	3	10	10	15	21	14	3*	4*	3*	11	1	10
19	0	0	24	14	4	5	5	2	0	2	4	9*	---	---	---	---	---	30*	10*	10*
20	6	7	18	14	1	2	2	4	0	4	1	1	23	15	2	3	5	5	1*	4
21	6	9	20	13	3	4	3	10	2	8	5	7	16*	11*	3	4	1*	9	4*	5
22	6	8	19	13	2	3	3	2	1	1	1	1	22	15	2	3	4	4	0	4*
23	1	1	18	11	2	3	4	4	0	4	2	3	21	12	4	5	4	7	0	7*
24	4	4	22	15	3	4	3	7	2	5	5	7	21	15	3	4	2*	11*	8*	3
25	14	19	20	13	3	4	3	6	0	6	4	5	19	14	2*	3*	2*	12*	2*	10*
26	0	0	22	15	4	5	2	2	0	2	6*	6	20*	14*	3*	4*	2	3	0	3
27	5	5	24	15	4	5	4	9	1	8	8	8	22*	14*	3*	4*	4	10	2*	8
28	0	0	22	13	3	4	5	1	0	1	3	4	23	14	3	4	5	7*	1*	6*
29	7	7	21	13	3	4	4	3	0	3	6	7	22	14	3	4	4	4	2*	2
30	0	0	19	11	2	3	5	5	1	4	13*	18*	21	14	2	3	4*	6	1	5
31	13	17	22	15	1	2	5	3	0	3	15	23	18*	15	2	3	0*	1	0	1
32	4	6	21	12	4	5	4	5	1	4	4	6	24	15	4	5	4	4	1	3
33	2	2	21	15	3	4	2	7	3	4	3	5	18*	13*	2*	3*	2	23*	10*	10*
34	2	2	21	15	3	4	2	7	3	4	6	8	23	15	2	3*	5*	4	1	3
35	0	0	23	15	4	5	3	9	1	8	7*	7*	24	15	3	4*	5*	11	2*	9
36	3	5	23	15	2	3	5	6	0	6	17*	39*	19*	15	2	3	1*	24*	10*	10*

	Pre-Injury Baseline Child SCAT5 Scores										Post-Injury Sideline Child SCAT5 Scores									
	Symptom		SAC-C					mBESS			Symptom		SAC-C					mBESS		
Subject	Total	Severity	Total	IM	DB	Con	DR	Total	TL	SL	Total	Severity	Total	IM	DB	Con	DR	Total	TL	SL
37	3	5	23	15	2	3	5	6	0	6	19*	43*	19*	15	3	4	0*	14*	4*	10*
38	21	32	22	14	3	4	4	4	0	4	18	31	18*	12*	2*	3*	3*	3	1*	2
39	7	7	23	14	3	4	5	5	1	4	11	16*	23	14	3	4	5	10*	3*	7*
40	20	28	25	15	4	6	4	3	1	2	16	22	22*	13*	3*	4*	5	9*	4*	5*
41	0	0	17	11	2	3	3	3	3	0	15*	20*	24*	14	4	5	5	15*	5*	10*
42	0	0	21	14	3	4	3	10	0	10	9*	9*	23	15	3	4	4	12	2*	10
43	---	---	---	---	---	---	---	---	---	---	13	22	20	13	3	4	3	21	10	10
44	---	---	---	---	---	---	---	---	---	---	13	31	23	15	4	5	3	1	0	1
45	---	---	---	---	---	---	---	---	---	---	12	19	12	10	2	2	0	4	1	3
46	---	---	---	---	---	---	---	---	---	---	16	28	24	15	3	4	5	1	1	0
47	---	---	---	---	---	---	---	---	---	---	15	25	18	12	1	2	4	12	3	7
48	---	---	---	---	---	---	---	---	---	---	20	47	13	9	2	3	1	9	4	4
49	---	---	---	---	---	---	---	---	---	---	19	34	---	---	---	---	---	---	---	---
50	---	---	---	---	---	---	---	---	---	---	13	24	18	12	2	3	3	3	0	3
51	---	---	---	---	---	---	---	---	---	---	18	34	25	15	5	6	4	13	3	10
52	---	---	---	---	---	---	---	---	---	---	18	31	20	13	3	4	3	12	2	10
53	---	---	---	---	---	---	---	---	---	---	3	6	20	12	3	4	4	11	1	10
Total (n)	42	42	42	42	42	42	42	42	42	42	53	53	50	51	51	51	50	52	52	52

Note. SAC-C = Standardized Assessment of Concussion - Child Version, IM = Immediate Memory, DB = Digits Backwards, Con = Concentration, DR= Delayed Recall, mBESS = Modified Balance Error Scoring System, TL = Tandem Leg, SL = Single Leg. The reliable change cutoffs corresponded with the following: total symptom score ≥5, symptom severity ≥7, SAC-C total score ≤-2, immediate memory ≤-1, digits backwards ≤-1, concentration ≤-1, delayed recall ≤-1, total mBESS score ≥4, tandem leg ≥1, and single leg ≥2.
*Demarcates scores that were reliably worse upon sideline assessments.

Table 25. Difference score ranges for test-retest and baseline-sideline scores, cutoffs for reliable and uncommon change scores on the Child SCAT5, and percent of concussed middle school age children that fell beyond the cutoffs.

Child SCAT5 Component	Test-Rest Difference Score Ranges	Baseline-Sideline Difference Score Ranges	Reliable Change[a] Score Cutoffs	Reliable Change[a] % of Concussed Sample	Uncommon Change[b] Score Cutoffs	Uncommon Change[b] % of Concussed Sample
Symptom						
Total Score	-21 to 19	-10 to 16	+5	29.3	+6	24.4
Severity	-33 to 33	-14 to 38	+7	29.3	+10	14.6
SAC-C						
Total Score	-6 to 11	-15 to 7	-2	45.0	-3	32.5
Immediate Memory	-5 to 9	-9 to 3	-1	39.0	-1	39.0
Digits Backwards	-3 to 3	-3 to 2	-1	41.5	-1	41.5
Concentration	-3 to 3	-3 to 2	-1	41.5	-1	41.5
Delayed Recall	-4 to 4	-5 to 3	-1	40.0	-1	40.0
mBESS						
Total	-14 to 13	-5 to 30	+4	40.5	+5	38.1
Tandem Leg	-4 to 7	-5 to 10	+1	61.9	+2	45.2
Single Leg	-10 to 8	-4 to 10	+2	50.0	+3	45.2

Note. SAC-C = Standardized Assessment of Concussion - Child Version, mBESS = Modified Balance Error Scoring System.
[a]Reliable change in scores was selected as the 20th percentile as a cutoff by reliable change estimates of the test-retest data (n=219, P. M. Kelshaw, unpublished data, February 2020).
[b]Uncommon change in scores was selected as the 15th percentile as a cutoff by reliable change estimates of the test-retest data (n=219, P. M. Kelshaw, unpublished data, February 2020).

Sideline and Normative Comparisons. The Child SCAT5 scores for each injured child are compared to normative reference values in

Table 26. The majority of children had one or more post-injury normative scores in the below normal or above normal, or worse, classification ranges on the symptom scale (number or severity), SAC-C total, or mBESS (40/53; 75.5%). Further, the majority of children had one or more post-injury normative scores in the below normal or above normal, or worse, classification ranges among all Child SCAT5 component scores (45/53; 84.9%). Moreover, 67.9% (36/53) of children had one or more post-injury scores that were in the unusually high or unusually low, or worse, classification ranges. Children's post-injury Child SCAT5 scores were significantly worse than the normative reference values, with small effect sizes (see Table 27). Using age norms, there were statistically significant differences in the proportions of children whose post-injury scores declined in normative classifications on the SAC-C using age-based norms, and the total mBESS score using both gender-based and age-based norms (see Table 28). The distribution of change in normative classifications by gender and age ranks during sideline Child SCAT5 assessments are illustrated in Figures 12 & 13. Summary statistics for Child SCAT5 scores, stratified by normative classification, baseline assessment, and sideline assessment are presented in Table 27.

Table 26. Post-injury SCAT5 scores for 53 children and corresponding normative classifications.

	Symptom		SAC-C					mBESS		
Subject	Total	Severity	Total	IM	DB	Con	DR	Total	*TL*	*SL*
1	9	12	8***	6***	1***	1***	1**	30***	10	10
2	10	16	19*	11**	4	5	3	2	0	2
3	15*	36**	5***	2***	2	3	0***	11*	1	10
4	2	2	21	15	2	3	3	0	0	0
5	3	3	25	15	5	6	4	7	2	5
6	3	4	19*	12*	3	4	3	6	3	3
7	7	7	20	13	1***	2**	5	5	1	4
8	17**	20*	21	13	3	4	4	6	4	2
9	10	17*	20	15	2	3	2*	13***	3	10
10	21***	46***	16***	11**	2	3	2*	30***	10	10
11	10	16	23	14	4	5	4	17***	7	8
12	10	13	23	14	4	5	4	9*	2	7
13	16*	30**	19*	12*	3	4	3	30***	10	10
14	8	10	21	15	3	4	2*	7	1	6
15	18**	34***	---	13	1***	2**	---	30***	10	10
16	5	6	16**	9***	2	3	4	6	2	4
17	12	29**	20	12*	2	3	5	12**	2	10
18	10	15	21	14	3	4	3	11**	1	10
19	4	9	---	---	---	---	---	30***	10	10
20	1	1	23	15	2	3	5	5	1	4
21	5	7	16***	11**	3	4	1**	9*	4	5
22	1	1	22	15	2	3	4	4	0	4
23	2	3	21	12*	4	5	4	7	0	7
24	5	7	21	15	3	4	2*	11**	8	3
25	4	5	19*	14	2	3	2*	12**	2	10
26	6	6	20	14	3	4	2*	3	0	3
27	8	8	22	14	3	4	4	10*	2	8
28	3	4	23	14	3	4	5	7	1	6
29	6	7	22	14	3	4	4	4	2	2
30	13*	18*	21	14	2	3	4	6	1	5
31	15*	23*	18**	15	2	3	0***	1	0	1
32	4	6	24	15	4	5	4	4	1	3
33	3	5	18**	13	2	3	2*	23***	10	10
34	6	8	23	15	2	3	5	4	1	3
35	7	7	24	15	3	4	5	11**	2	9
36	17**	39***	19*	15	2	3	1**	24***	10	10
37	19**	43***	19*	15	3	4	0***	14***	4	10
38	18**	31***	18**	12*	2	3	3	3	1	2
39	11	16	23	14	3	4	5	10*	3	7
40	16*	22*	22	13	3	4	5	9*	4	5
41	15*	20*	24	14	4	5	5	15***	5	10
42	9	9	23	15	3	4	4	12**	2	10
43	13*	22*	20	13	3	4	3	21***	10	10
44	13*	31***	23	15	4	5	3	1	0	1
45	12	19*	12***	10***	2	2**	0***	4	1	3
46	16*	28**	24	15	3	4	5	1	1	0
47	15*	25**	18**	12*	1***	2**	4	12**	3	7
48	20***	47***	13***	9***	2	3	1**	9*	4	4
49	19**	34***	---	---	---	---	---	---	---	---
50	13*	24**	18**	12*	2	3	3	3	0	3
51	18**	34***	25	15	5	6	4	13**	3	10
52	18**	31***	20	13	3	4	3	12**	2	10
53	3	6	20	12*	3	4	4	11**	1	10
Total (n)	53	53	50	51	51	51	50	52	52	52

Note. SAC-C = Standardized Assessment of Concussion - Child Version, IM = Immediate Memory, DB = Digits Backwards, Con = Concentration, DR= Delayed Recall, mBESS = Modified Balance Error Scoring System, TL = Tandem Leg, SL = Single Leg. Normative classifications were generated from our prior work (P. M. Kelshaw, unpublished data, December 2019). The normative classifications that are noted in this table reflect the ranges of norms that we generated for total sample (N=1,000, P. M. Kelshaw, unpublished data, December 2019). Additional information regarding these normative classifications are provided in Table 28. "Broadly normal" scores fell within the 25th or 75th percentile ranks. The "below/above normal" scores were defined as close as possible to the 24th or 76th percentile ranks. The "unusually low/high" scores corresponded with the 10th and 90th percentile ranks.

“Extremely low/high” corresponded with the 2nd and 98th percentile ranks. Labels for normative values were anchored by the direction of scores that indicate better performance.

Scores without a demarcation (*) were classified as “Broadly Normal”
*Denotes scores that were classified as “Above/Below Normal.”
**Denotes scores that were classified as “Unusually High/Low
***Denotes scores that were classified as “Extremely High/Low”
Normative classifications were not generated for single and tandem leg stances, as such they are not included in this table.

Table 27. Sideline Child SCAT5 results compared to individual baseline and a sample of middle school normative reference values.

Child SCAT5 Component	Middle School Norms (n=984)	Baseline Scores (n=42)	Sideline Scores (n=53)	Sideline compared to individual baseline[a]		Sideline compared to norms[b]	
				p	*r*	*p*	*r*
Symptoms							
Total Score	7.9 ± 5.8	6.5 ± 6.2	10.2 ± 6.0	**0.01**	**-0.43**	**<0.01**	**-0.12**
Severity	11.1 ± 9.6	10.0 ± 10.6	17.4 ± 13.0	**0.01**	**-0.39**	**<0.01**	**-0.14**
SAC-C							
Total Score	21.5 ± 2.3	21.2 ± 1.8	19.9 ± 4.0	0.12	-0.25	**<0.01**	**-0.09**
Immediate Memory	13.8 ± 1.5	13.7 ± 1.3	13.0 ± 2.5	0.31	-0.16	**0.02**	**-0.07**
Digits Backwards	3.1 ± 0.9	2.8 ± 0.9	2.7 ± 0.9	0.54	-0.10	**0.04**	**-0.06**
Concentration	4.1 ± 1.0	3.9 ± 0.9	3.7 ± 1.0	0.38	-0.14	**0.04**	**-0.07**
Delayed Recall	3.7 ± 1.2	3.8 ± 1.1	3.2 ± 1.5	0.13	-0.24	**0.01**	**-0.08**
mBESS							
Total Score	5.1 ± 3.8	5.8 ± 3.8	10.7 ± 8.3	**<0.01**	**-0.57**	**<0.01**	**-0.12**
Tandem Stance	1.3 ± 1.6	1.4 ± 1.7	3.2 ± 3.4	**<0.01**	**-0.53**	**<0.01**	**-0.10**
Single Leg Stance	3.7 ± 2.7	4.5 ± 2.8	6.3 ± 3.4	**<0.01**	**-0.51**	**<0.01**	**-0.12**

Note. Descriptive statistics (M±SD) provided per Child SCAT5 component by sample norms, baseline scores, and sideline scores. The sideline scores were compared to the baseline scores by Wilcoxon Signed Rank analyses. Sideline scores were compared to middle school sample norms using Mann-Whitney U analyses. Effect sizes are estimated with $(r = \frac{z}{\sqrt{N}})$[157] and were interpreted according to available guidelines (i.e., *r*=.1, small; *r*=.3, medium; *r*=.5, large).[158]. Bolded values indicate statistical significance in score differences. SAC-C = Standardized Assessment of Concussion - Child Version, mBESS = Modified Balance Error Scoring System.

[a]Only sideline scores that had a paired baseline assessment were used for the Wilcoxon Signed Rank analyses.

[b]Baseline assessments of the sideline participants were removed from the normative sample for the Mann-Whitney U analyses.

Table 28. Normative classifications for the sample at sideline assessments and percent of the sample that changed classification categories at sideline assessments (n=42).

Child SCAT5 Component	Broadly Normal	Above/Below Normal	Unusually High/Low	Extremely High/Low	No Change	Improved	Worsened	χ^2, p-value
Gender-Based Classifications								
Total Symptoms	60.8	19.6	15.7	3.9	69.0	11.9	19.0	0.69, *p*=.41
Symptom Severity	51.0	19.6	7.8	21.6	57.1	14.3	28.6	2.00, *p*=.16
SAC-C Total Score	58.0	18.0	16.0	8.0	42.9	16.7	35.7	2.91, *p*=.09
Immediate Memory	68.6	15.7	7.8	7.8	61.9	14.3	21.4	0.60, *p*=.44
Digits Backwards	76.5	15.7	7.8	---	78.6	7.1	11.9	0.50, *p*=.48
Concentration	74.5	15.7	7.8	2.0	78.6	7.1	11.9	0.50, *p*=.48
Delayed Recall	70.0	14.0	8.0	8.0	61.9	9.5	23.8	2.57, *p*=.11
mBESS Total Score	41.2	19.6	15.7	23.5	42.9	11.9	45.2	**8.16, *p*=.04**
Age-Based Classifications								
Total Symptoms	58.8	15.7	21.6	3.9	73.8	9.5	16.7	0.82, *p*=.37
Symptom Severity	52.9	17.6	7.8	21.6	61.9	14.3	23.8	1.00, *p*=.32
SAC-C Total Score	54.0	22.0	10.0	14.0	40.5	14.3	40.5	**5.26, *p*=.02**
Immediate Memory	68.6	15.7	7.8	7.8	61.9	14.3	21.4	0.60, *p*=.44
Digits Backwards	72.5	17.6	3.9	5.9	66.7	11.9	19.0	0.69, *p*=.41
Concentration	72.5	17.6	2.0	7.8	66.7	11.9	19.0	0.69, *p*=.41
Delayed Recall	70.0	14.0	8.0	8.0	61.9	9.5	23.8	2.57, *p*=.11
mBESS Total Scores	45.1	11.8	21.6	21.6	52.4	7.1	40.5	**9.80, *p*=.02**

Note. SAC-C = Standardized Assessment of Concussion - Child Version. mBESS = Modified Balance Error Scoring System. Standardized Assessment of Concussion - Child Version. mBESS = Modified Balance Error Scoring System. Normative classifications are derived from Kelshaw et al (P. M. Kelshaw, unpublished data, December 2019) from a sample of middle school student-athletes that are also represented in the present study. “Broadly normal” scores fell within the 25th or 75th percentile ranks. The “below/above normal” scores were defined as close as possible to the 24th or 76th percentile ranks. The “unusually low/high” scores corresponded with the 10th and 90th percentile ranks. “Extremely low/high” corresponded with the 2nd and 98th percentile ranks. Labels for normative values were anchored by the direction of scores that indicate better performance.

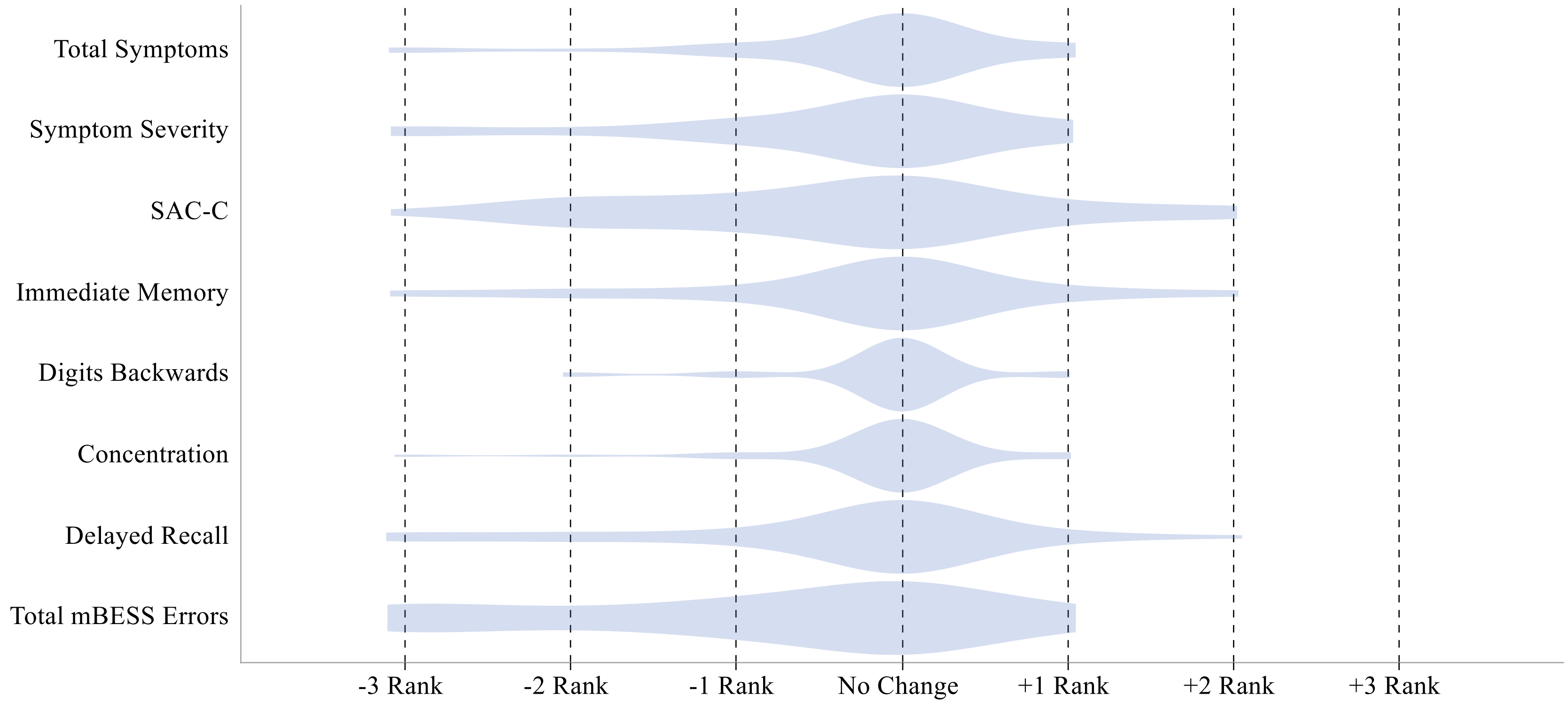

Figure 12. Distribution of change in normative classifications by gender ranks at day-of-injury Child SCAT5 assessment.

Note. Normative rank changes are based upon the normative classifications created by Kelshaw et al (P. M. Kelshaw, unpublished data, December 2019) "No change" indicates that there was no change in the normative classification sideline assessments, "+1 Rank" indicates that the athlete improved by one ranking, "+2 Rank" indicates that the athlete improved by 2 rankings, etc. "-1 Rank" indicates that the athlete worsened by 1 rank, "-2 Rank" indicates that the athlete worsened by two normative ranks, etc. SAC-C = Standardized Assessment of Concussion - Child Version, mBESS = Modified Balance Error Scoring System

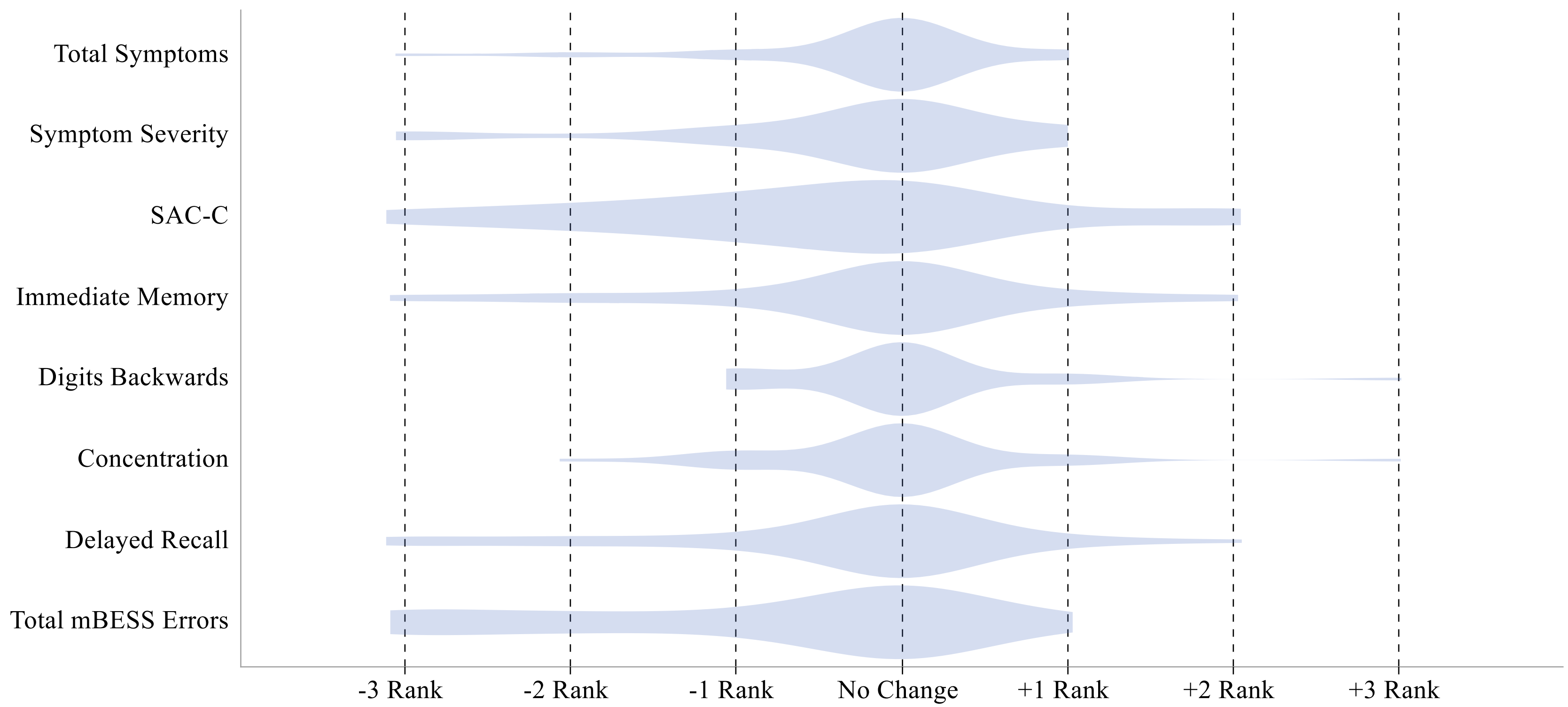

Figure 13. Distribution of change in normative classifications by age ranks at day-of-injury Child SCAT5 assessment.

Note. Normative rank changes are based upon the normative classifications created by Kelshaw et al (P. M. Kelshaw, unpublished data, December 2019) "No change" indicates that there was no change in the normative classification at sideline assessments, "+1 Rank" indicates that the athlete improved by one ranking, "+2 Rank" indicates that the athlete improved by 2 rankings, etc. "-1 Rank" indicates that the athlete declined by 1 rank, "-2 Rank" indicates that the athlete declined by two normative ranks, etc. SAC-C = Standardized Assessment of Concussion - Child Version, mBESS = Modified Balance Error Scoring System.

Combined Comparisons of Pre-injury Baselines and Normative Reference Values. A comparison of both interpretation methods is presented in Table 29. Applying the reliable change methodology among the baseline and sideline sample (n=42), comparing personal baseline scores to post-injury scores, there were 13 children who were not detected as injured by any of the primary Child SCAT5 scores (31.0%, 13/42, subject numbers: 4-7, 14, 20, 22, 23, 26, 28, 29, 32, 34). Similarly, applying the normative comparison methodology, there were 13 children who were not detected as injured by any of the primary Child SCAT5 scores (31.0%, 13/42, subject numbers: 5, 8, 9, 14, 17, 18, 20, 22, 23, 29, 32, 34, 28). Applying both methods simultaneously, there were 8 children who were not identified by any of the primary SCAT5 scores (8/42, 19.0%, subject numbers: 5, 14, 20, 22, 23, 29, 32, 34). In short, majority of the sample were detected as impaired upon applying the normative reference values (69.0%), reliable change estimates (69.0%), and when applying both methods (81.0%).

Table 29. Baseline and post-injury scores for all participants and corresponding reliable changes and comparisons to normative reference values.

	Baseline, Preseason				Post Injury							
	Symptoms		SAC-C	mBESS	Symptoms				SAC-C		mBESS	
Subject	Total	Severity	Total	Total	Total	NC	Severity	NC	Total	NC	Total	NC
1	4	7	23	8	9*	BN	12	BN	8*	EL	30*	EH
2	5	7	21	1	10*	BN	16*	BN	19*	BlN	2	BN
3	1	1	19	5	15*	AN	36*	UH	5*	EL	11*	AN
4	1	1	24	1	2	BN	2	BN	21*	BN	0	BN
5	6	6	21	4	3	BN	3	BN	25	BN	7	BN
6	0	0	22	9	3	BN	4	BN	19*	BlN	6	BN
7	1	1	22	7	7*	BN	7	BN	20*	BN	5	BN
8	17	29	22	6	17	UH	20	AN	21	BN	6	BN
9	15	25	18	11	10	BN	17	AN	20	BN	13	EH
10	11	22	21	0	21*	EH	46*	EH	16*	EL	30*	EH
11	9	13	22	4	10	BN	16	BN	23	BN	17*	EH
12	11	22	21	1	10	BN	13	BN	23	BN	9*	AN
13	14	22	21	8	16	AN	30*	UH	19*	BlN	30*	EH
14	4	5	20	4	8	BN	10	BN	21	BN	7	BN
15	17	28	19	14	18	UH	34	EH	---	---	30*	EH
16	6	7	22	8	5	BN	6	BN	16*	UL	6	BN
17	16	39	21	17	12	BN	29	UH	20	BN	12	UH
18	12	19	22	13	10	BN	15	BN	21	BN	11	UH
19	0	0	24	2	4	BN	9*	BN	---	---	30*	EH
20	6	7	18	4	1	BN	1	BN	23	BN	5	BN
21	6	9	20	10	5	BN	7	BN	16*	EL	9	AN
22	6	8	19	2	1	BN	1	BN	22	BN	4	BN
23	1	1	18	4	2	BN	3	BN	21	BN	7	BN
24	4	4	22	7	5	BN	7	BN	21	BN	11*	UH
25	14	19	20	6	4	BN	5	BN	19	BlN	12*	UH
26	0	0	22	2	6*	BN	6	BN	20*	BN	3	BN
27	5	5	24	9	8	BN	8	BN	22*	BN	10	AN
28	0	0	22	1	3	BN	4	BN	23	BN	7*	BN
29	7	7	21	3	6	BN	7	BN	22	BN	4	BN
30	0	0	19	5	13*	AN	18*	AN	21	BN	6	BN
31	13	17	22	3	15	AN	23	AN	18*	UL	1	BN
32	4	6	21	5	4	BN	6	BN	24	BN	4	BN
33	2	2	21	7	3	BN	5	BN	18*	UL	23*	EH
34	2	2	21	7	6	BN	8	BN	23	BN	4	BN
35	0	0	23	9	7*	BN	7*	BN	24	BN	11	UH
36	3	5	23	6	17*	UH	39*	EH	19*	BlN	24*	EH
37	3	5	23	6	19*	UH	43*	EH	19*	BlN	14*	EH
38	21	32	22	4	18	UH	31	EH	18*	UL	3	BN
39	7	7	23	5	11	BN	16*	BN	23	BN	10*	AN
40	20	28	25	3	16	AN	22	AN	22*	BN	9*	AN
41	0	0	17	3	15*	AN	20*	AN	24*	BN	15*	EH
42	0	0	21	10	9*	BN	9*	BN	23	BN	12	UH

Note. SAC-C = Standardized Assessment of Concussion - Child Version, mBESS = Modified Balance Error Scoring System. NC=normative comparisons. BN=Broadly Normal, B1N=Below Normal, AN=Above Normal, UH=Unusually High, EH=Extremely High. The reliable change cutoffs corresponded with the following: total symptom score $\geq$5, symptom severity $\geq$7, SAC-C total score $\leq$-2, immediate memory $\leq$-1, digits backwards $\leq$-1, concentration $\leq$-1, delayed recall $\leq$-1, total mBESS score $\geq$4, tandem leg $\geq$1, and single leg $\geq$2.

*Demarcates post-injury scores that were reliably worse compared to pre-injury baseline scores.

Discussion

This is the first study to use the Child SCAT5 to examine the ultra acute effects of sport-related concussion in children and adolescents. Our findings contribute to a growing body of research on sideline concussion assessment instruments,[87,93,184] and may further characterize the ultra acute manifestation of concussion in children. Moreover, important findings regarding the clinical use of the Child SCAT5 emerged from this study. First, the symptom algorithm we generated provided important insight into the ultra acute manifestation of symptoms in children following concussion, and may be particulary useful for identifying injured children. Second, the comparison of post-injury scores to baseline scores yielded medium to large effect sizes, in contrast to the normative sample comparison in which small effect sizes were observed. Finally, the individual post-injury scores reported in Tables 24, 26, and 29 provide the greatest clinical insight into the manifestation of concussion, as measured by the Child SCAT5.

Considerable debate exists regarding the best method to appraise a patient's post-injury performance on concussion assessment instruments following an injury or suspected injury.[153,185–188] A commonly accepted method involves comparing a patient's post-injury performance to his or her own personal, pre-injury baseline scores.[188] Alternatively, others recommend a comparison of post-injury scores to normative reference values.[93,188] In this study, significantly poorer scores were observed upon post-injury assessments compared to individual baselines for symptom and balance component scores, with medium and large effects, respectively. The cognitive measures (i.e., the SAC-C) were not statistically significantly different upon pre-injury and post-injury comparisons. Further, 69% (n=29/42) of the sample obtained at least 1 reliably worse score from baseline to post-injury assessments. When comparing the post-injury sample to the normative reference sample, all Child SCAT5 component scores were statistically significantly poorer for the post-injury sample, with small effects. However, the application of the normative reference classifications to the post-injury scores did detect impairment in 69% (n=29/42) of the sample. When integrating both methodologies (reliable change cutoffs and normative reference classifications), impairment was detected in at least one Child SCAT5 component score for 81% (n=34/42) of the sample. Combining both methods for interpreting post-injury test scores was more useful than either method in isolation.

Children diagnosed with a concussion acutely presented, on average, an increase of 3 or more total symptoms, and an increase of 5 or more for symptom severity compared to their baseline scores. “I have headaches” and “I feel dizzy” were among the most commonly endorsed symptoms during sideline assessments (100% and 66%, respectively). These symptoms were less commonly endorsed at baseline (44% and 19%, respectively). In addition, “I feel like the room is spinning” was endorsed by 41% of the concussed sample, and only endorsed by 10% of the baseline sample. We generated a symptom algorithm that may have important implications for evaluating the ultra acute manifestation of concussion in children. Specifically, symptoms of headache, dizziness, feeling that the room is spinning, feeling faint, experiencing blurry vision, feeling sick, and feeling tired were more commonly endorsed, and with greater burden (i.e., symptom severity) during sideline assessments, than baseline assessments, with large effect sizes.

These findings suggest that a child should be considered injured if he or she reports these symptoms on the sideline, whether baseline values are available or not. Further, "I get distracted easily," and "I have trouble paying attention" were among the most commonly endorsed at baseline (51% and 44%, respectively). Research suggests that these symptoms are commonly endorsed at greater rates for children with ADHD at baseline,[129] and they are commonly endorsed by children who do not have ADHD at baseline. Therefore, these symptoms are likely less useful for the sideline evaluation of concussion.

In regards to cognitive assessments on the Child SCAT5 (e.g., SAC-C, immediate memory, etc.), there were no statistically significant differences between individual baseline and sideline scores. However, the sideline comparison to baseline scores revealed larger effect sizes than the comparison to the normative scores (r=-.25 vs. r= -0.09, respectively). Approximately 39-45% fell beyond reliable change cutoffs, and 36-41% worsened in classification by the normative reference values for SAC-C components. This suggests that both the reliable change cutoffs and the normative classifications will have similar sensitivities to impairment on cognitive functioning. Although this research has not been done on the SAC-C previously, these findings are consistent with prior research on the SAC in professional atheltes.[93] Further, previous studies with the SAC have shown that it is sensitive to cognitive deficits immediately after concussion in high school[87,117] and collegiate[87] athletes, and its sensitivity declines considerably by 48 hours followingconcussion.[118] However, the SAC has ceiling effects[29,87,123] and low temporal stability (P. M. Kelshaw, unpublished data, February

2020). Therefore, we recommend the use of acute sideline cognitive assessments (i.e., SAC-C) in conjunction with other assessments to inform clinical decision making.

For sideline balance assessments, our findings support prior work using the mBESS, in which significantly poorer scores were observed acutely following a concussion compared to baseline scores in high school and collegiate athletes.[73,87] The baseline and sideline comparisons of the mBESS error scores had the largest effect sizes of all the Child SCAT5 component scores. On average, the children in this cohort committed 4 or more total mBESS errors during sideline assessments compared to their baseline performance, consistent with the reliable change cutoff (+4 errors, P. M. Kelshaw, unpublished data, December 2019). In addition, 41% of the sample fell beyond reliable change cutoffs for the mBESS total score, 62% in tandem stance, and 50% in single leg stance. Of note, 92% of the sideline assessments received 0 errors on double leg stance. These proportions were similar in comparison to the participants' post-injury normative classifications. There was a significant worsening (41-45%) in performance relative to normative classifications for mBESS total scores when examining the normative classification ranges. This finding is also in alignment with a similar research design of the SCAT3.[93] The mBESS component of the Child SCAT5 was useful for identifying balance deficits associated with concussion in this sample. As such, we recommend the use of acute sideline mBESS assessments to further inform decision-making.

Limitations. This study has several limitations. First, this study included children between the ages of 11 and 13 from a demographically diverse and relatively low income school district in Virginia; it is not representative of the broader middle school population that may be diagnosed with a concussion. Second, research has shown that symptoms of concussion may take longer than 24 hours to manifest,[180,189,190] therefore it is important for future research to include other assessment time intervals post injury. Third, although children reported greater symptoms and performed more poorly on cognitive testing and balance testing following concussion, on average, compared to their baseline pre-injury test scores, interpreting baseline to post-injury change scores may be misleading if children endorse a high number and severity of symptoms at baseline. Further, baseline test scores can vary in association with demographic characteristics (e.g., gender,[85,86,191,192] age,[85,86,191] and native language[151]), health history (e.g., ADHD,[129,193,194] learning disabilities,[99] and depression/anxiety[73,195]) and activities of daily living (e.g., exercise,[146] quality of sleep,[154,155] and stress[196]). Using normative classification ranges also has limitations because of the broad ranges of scores within each classification, as such there is a risk of misclassification of individuals who naturally score high (e.g., high intelligence) or low (e.g., ADHD, or low intelligence) on concussion assessments.[152,153] It is important to note that concussion is an individualized injury, as such some concussed children may not be detected as impaired using reliable change cutoffs (as observed in 13/42, 31%, of the middle school sample), normative reference classifications (as observed in 13/42, 31%, of the middle school sample), or an integration of both methods (as observed in 8/42, 19% of the middle school sample). Further, the Child SCAT5 should be viewed as tool to gather data that informs clinical judgment and should not be used in isolation to diagnose a concussion.

Conclusion

The Child SCAT5 was useful for measuring the ultra acute effects of concussion in children. Certain symptoms on the symptom scale are more clinically useful for sideline assessment than others. When considering the test as a whole, most injured children obtained worse scores on at least one component (symptoms, cognition, or balance) compared to their baseline pre-injury test scores. Moreover, most injured children obtained one or more concerning scores compared to normative reference values. Both interpretation methods, baseline to post-injury comparisons and normative reference values, had limitations. Additional research is needed to refine the clinical usefulness of the Child SCAT5 for measuring the acute effects of concussion.

Chapter Six: General Discussion

This dissertation was conducted to better understand the assessment of concussion in children. Ultimately, this program of research provides a meaningful and needed contribution to the field of pediatric concussion management. The assessment of concussion in children is complex as reflected in this program of research. In summary, our work, focused on the Child SCAT5, has generated normative reference values, evidence of temporal stability, reliable change cutoffs, and information relating to how to interpret the test when used on the sideline to evaluate concussed children. Ultimately, the Child SCAT5 was useful for measuring the ultra acute effects of concussion in children. Future research should replicate and extend these findings to include greater time intervals post-injury, and larger samples of children, to further refine the assessment of concussion in children.

Study I. This study examined whether baseline Child SCAT5 symptom scores and test performances are associated with demographic characteristics and health history in middle school children. Our findings provide clinicians normative reference values for interpreting Child SCAT5 results stratified by demographic characteristics. Overall, we observed that gender, age, and language spoken at home are associated with Child SCAT5 test results; however, the magnitudes of the observed differences were generally small to negligible. This study presents score ranges stratified by demographic characteristics for what is considered to be “normal” performance, which can assist clinicians interpreting Child SCAT5 results in healthy children.

Study II. Within our cohort of middle school-age student-athletes, the Child SCAT5 had poor one-year temporal stability. This makes comparisons of performances across serial administrations for clinical purposes challenging. However, we observed that middle school student-athletes were likely to score within the same normative classification range across serial baseline performances of the Child SCAT5. Further, clinicians can incorporate the cutoff scores for interpreting retest performance following a suspected injury.

Study III. This study was the first to investigate ultra acute symptoms, cognitive functioning, and balance in middle school children who sustained a sport-related concussion. The symptom algorithm we generated provide important insight in the manifestation of concussion in the middle school sample. Further, most concussed children obtained worse scores on at least one component (symptoms, cognition, or balance) compared to their baseline pre-injury test scores. Moreover, most injured children obtained one or more concerning scores compared to normative reference values.

Limitations. A shared limitation among all three studies is that our data reflect Child SCAT5 scores from middle school student-athletes and thus our findings may not be generalizable to all pediatric athletes. In addition, each study shares the collective limitation of varying testing environments by the location of the sport in which the athlete participates in, thus potentially introducing environmental influences into the methodologies. Further, the normative reference values only allow for clinical interpretation by gender, age, or language, rather than a model that can account for an interaction among these characteristics. Regarding ultra acute effects of concussion, Study III only includes the immediate post-injury sideline Child SCAT5 scores, and thus is limited in that symptoms of concussion likely evolve over hours and certainly over the course of 24 hours.[180,189,190]

Recommendations for future research. Additional research is needed to refine the clinical usefulness of the Child SCAT5 for measuring the acute effects of concussion. It is important that the findings of the present studies undergo further recursive investigation to advance care for children in regards to concussion. Specifically, the next logical progression of this work is to replicate with larger samples, diversify the intervals of assessment administration, and extend these findings into monitoring changes sub-acutely following a concussion.

Appendix A

George Mason University Institutional Review Board Approval Letter

Office of Research Development, Integrity, and Assurance

Research Hall, 4400 University Drive, MS 6D5, Fairfax, Virginia 22030
Phone: 703-993-5445; Fax: 703-993-9590

DATE:	July 22, 2019
TO:	Shane Caswell, PhD
FROM:	George Mason University IRB
Project Title:	[717033-7] Tracking Pediatric Sports-Related Injuries
Reference:	OSP #115295/#11598B/#11778A/11856B
SUBMISSION TYPE:	Amendment/Modification
ACTION:	DETERMINATION OF NOT HUMAN SUBJECT RESEARCH
DECISION DATE:	July 22, 2019

Thank you for your submission of Amendment/Modification materials for this project. The Institutional Review Board (IRB) Office has determined this project does not meet the definition of human subject research under the purview of the IRB according to federal regulations.

Please remember that if you modify this project to include human subjects research activities, you are required to submit revisions to the IRB prior to initiation.

If you have any questions, please contact Bess Dieffenbach at 703-993-5593 or edieffen@gmu.edu. Please include your project title and reference number in all correspondence with this committee.

Please note that department or other approvals may be required to conduct your research.

GMU IRB Standard Operating Procedures can be found here: https://rdia.gmu.edu/topics-of-interest/human-or-animal-subjects/human-subjects/human-subjects-sops/

Appendix B

Child Sport Concussion Assessment Tool, 5th Edition

BJSM Online First, published on April 26, 2017 as 10.1136/bjsports-2017-097492childscat5
To download a clean version of the SCAT tools please visit the journal online (http://dx.doi.org/10.1136/bjsports-2017-097492childscat5)

Child SCAT5®

SPORT CONCUSSION ASSESSMENT TOOL
FOR CHILDREN AGES 5 TO 12 YEARS
FOR USE BY MEDICAL PROFESSIONALS ONLY

supported by

Patient details

Name: ____________________

DOB: ____________________

Address: ____________________

ID number: ____________________

Examiner: ____________________

Date of Injury: ____________________ Time: ____________________

WHAT IS THE CHILD SCAT5?

The Child SCAT5 is a standardized tool for evaluating concussions designed for use by physicians and licensed healthcare professionals[1].

If you are not a physician or licensed healthcare professional, please use the Concussion Recognition Tool 5 (CRT5). The Child SCAT5 is to be used for evaluating Children aged 5 to 12 years. For athletes aged 13 years and older, please use the SCAT5.

Preseason Child SCAT5 baseline testing can be useful for interpreting post-injury test scores, but not required for that purpose. Detailed instructions for use of the Child SCAT5 are provided on page 7. Please read through these instructions carefully before testing the athlete. Brief verbal instructions for each test are given in italics. The only equipment required for the tester is a watch or timer.

This tool may be freely copied in its current form for distribution to individuals, teams, groups and organizations. It should not be altered in any way, re-branded or sold for commercial gain. Any revision, translation or reproduction in a digital form requires specific approval by the Concussion in Sport Group.

Recognise and Remove

A head impact by either a direct blow or indirect transmission of force can be associated with a serious and potentially fatal brain injury. If there are significant concerns, including any of the red flags listed in Box 1, then activation of emergency procedures and urgent transport to the nearest hospital should be arranged.

Key points

- Any athlete with suspected concussion should be REMOVED FROM PLAY, medically assessed and monitored for deterioration. No athlete diagnosed with concussion should be returned to play on the day of injury.
- If the child is suspected of having a concussion and medical personnel are not immediately available, the child should be referred to a medical facility for urgent assessment.
- Concussion signs and symptoms evolve over time and it is important to consider repeat evaluation in the assessment of concussion.
- The diagnosis of a concussion is a clinical judgment, made by a medical professional. The Child SCAT5 should NOT be used by itself to make, or exclude, the diagnosis of concussion. An athlete may have a a concussion even if their Child SCAT5 is "normal".

Remember:

- The basic principles of first aid (danger, response, airway, breathing, circulation) should be followed.
- Do not attempt to move the athlete (other than that required for airway management) unless trained to do so.
- Assessment for a spinal cord injury is a critical part of the initial on-field assessment.
- Do not remove a helmet or any other equipment unless trained to do so safely.

1

Name: ____________________

DOB: ____________________

Address: ____________________

ID number: ____________________

Examiner: ____________________

Date: ____________________

IMMEDIATE OR ON-FIELD ASSESSMENT

The following elements should be assessed for all athletes who are suspected of having a concussion prior to proceeding to the neurocognitive assessment and ideally should be done on-field after the first first aid / emergency care priorities are completed.

If any of the "Red Flags" or observable signs are noted after a direct or indirect blow to the head, the athlete should be immediately and safely removed from participation and evaluated by a physician or licensed healthcare professional.

Consideration of transportation to a medical facility should be at the discretion of the physician or licensed healthcare professional.

The GCS is important as a standard measure for all patients and can be done serially if necessary in the event of deterioration in conscious state. The cervical spine exam is a critical step of the immediate assessment, however, it does not need to be done serially.

STEP 1: RED FLAGS

RED FLAGS:

- **Neck pain or tenderness**
- **Double vision**
- **Weakness or tingling/ burning in arms or legs**
- **Severe or increasing headache**
- **Seizure or convulsion**
- **Loss of consciousness**
- **Deteriorating conscious state**
- **Vomiting**
- **Increasingly restless, agitated or combative**

STEP 2: OBSERVABLE SIGNS

Witnessed ☐ Observed on Video ☐

Lying motionless on the playing surface	Y	N
Balance / gait difficulties / motor incoordination: stumbling, slow / laboured movements	Y	N
Disorientation or confusion, or an inability to respond appropriately to questions	Y	N
Blank or vacant look	Y	N
Facial injury after head trauma	Y	N

STEP 3: EXAMINATION GLASGOW COMA SCALE (GCS)[2]

Time of assessment			
Date of assessment			
Best eye response (E)			
No eye opening	1	1	1
Eye opening in response to pain	2	2	2
Eye opening to speech	3	3	3
Eyes opening spontaneously	4	4	4
Best verbal response (V)			
No verbal response	1	1	1
Incomprehensible sounds	2	2	2
Inappropriate words	3	3	3
Confused	4	4	4
Oriented	5	5	5
Best motor response (M)			
No motor response	1	1	1
Extension to pain	2	2	2
Abnormal flexion to pain	3	3	3
Flexion / Withdrawal to pain	4	4	4
Localizes to pain	5	5	5
Obeys commands	6	6	6
Glasgow Coma score (E + V + M)			

CERVICAL SPINE ASSESSMENT

Does the athlete report that their neck is pain free at rest?	Y	N
If there is NO neck pain at rest, does the athlete have a full range of ACTIVE pain free movement?	Y	N
Is the limb strength and sensation normal?	Y	N

In a patient who is not lucid or fully conscious, a cervical spine injury should be assumed until proven otherwise.

OFFICE OR OFF-FIELD ASSESSMENT

STEP 1: ATHLETE BACKGROUND

Please note that the neurocognitive assessment should be done in a distraction-free environment with the athlete in a resting state.

Sport / team / school: ____________________

Date / time of injury: ____________________

Years of education completed: ____________________

Age: ____________________

Gender: M / F / Other

Dominant hand: left / neither / right

How many diagnosed concussions has the athlete had in the past?: ____________________

When was the most recent concussion?: ____________________

How long was the recovery (time to being cleared to play) from the most recent concussion?: ____________________ (days)

Has the athlete ever been:

Hospitalized for a head injury?	Yes	No
Diagnosed / treated for headache disorder or migraines?	Yes	No
Diagnosed with a learning disability / dyslexia?	Yes	No
Diagnosed with ADD / ADHD?	Yes	No
Diagnosed with depression, anxiety or other psychiatric disorder?	Yes	No

Current medications? If yes, please list: ____________________

STEP 2: SYMPTOM EVALUATION

The athlete should be given the symptom form and asked to read this instruction paragraph out loud then complete the symptom scale. For the baseline assessment, the athlete should rate his/her symptoms based on how he/she typically feels and for the post injury assessment the athlete should rate their symptoms at this point in time.

To be done in a resting state

Please Check: ☐ **Baseline** ☐ **Post-Injury**

Name: ____________________

DOB: ____________________

Address: ____________________

ID number: ____________________

Examiner: ____________________

Date: ____________________

2

Child Report[3]

	Not at all/ Never	A little/ Rarely	Somewhat/ Sometimes	A lot/ Often
I have headaches	0	1	2	3
I feel dizzy	0	1	2	3
I feel like the room is spinning	0	1	2	3
I feel like I'm going to faint	0	1	2	3
Things are blurry when I look at them	0	1	2	3
I see double	0	1	2	3
I feel sick to my stomach	0	1	2	3
My neck hurts	0	1	2	3
I get tired a lot	0	1	2	3
I get tired easily	0	1	2	3
I have trouble paying attention	0	1	2	3
I get distracted easily	0	1	2	3
I have a hard time concentrating	0	1	2	3
I have problems remembering what people tell me	0	1	2	3
I have problems following directions	0	1	2	3
I daydream too much	0	1	2	3
I get confused	0	1	2	3
I forget things	0	1	2	3
I have problems finishing things	0	1	2	3
I have trouble figuring things out	0	1	2	3
It's hard for me to learn new things	0	1	2	3
Total number of symptoms:			of 21	
Symptom severity score:			of 63	
Do the symptoms get worse with physical activity?			Y	N
Do the symptoms get worse with trying to think?			Y	N

Overall rating for child to answer:

	Very bad		Very good
On a scale of 0 to 10 (where 10 is normal), how do you feel now?	0 1 2 3 4 5 6 7 8 9 10		

If not 10, in what way do you feel different?:

Parent Report

The child:	Not at all/ Never	A little/ Rarely	Somewhat/ Sometimes	A lot/ Often
has headaches	0	1	2	3
feels dizzy	0	1	2	3
has a feeling that the room is spinning	0	1	2	3
feels faint	0	1	2	3
has blurred vision	0	1	2	3
has double vision	0	1	2	3
experiences nausea	0	1	2	3
has a sore neck	0	1	2	3
gets tired a lot	0	1	2	3
gets tired easily	0	1	2	3
has trouble sustaining attention	0	1	2	3
is easily distracted	0	1	2	3
has difficulty concentrating	0	1	2	3
has problems remembering what he/she is told	0	1	2	3
has difficulty following directions	0	1	2	3
tends to daydream	0	1	2	3
gets confused	0	1	2	3
is forgetful	0	1	2	3
has difficulty completing tasks	0	1	2	3
has poor problem solving skills	0	1	2	3
has problems learning	0	1	2	3
Total number of symptoms:				of 21
Symptom severity score:				of 63
Do the symptoms get worse with physical activity?			Y	N
Do the symptoms get worse with mental activity?			Y	N

Overall rating for parent/teacher/coach/carer to answer

On a scale of 0 to 100% (where 100% is normal), how would you rate the child now?

If not 100%, in what way does the child seem different?

3

STEP 3: COGNITIVE SCREENING

Standardized Assessment of Concussion - Child Version (SAC-C)[4]

IMMEDIATE MEMORY

The Immediate Memory component can be completed using the traditional 5-word per trial list or optionally using 10-words per trial to minimise any ceiling effect. All 3 trials must be administered irrespective of the number correct on the first trial. Administer at the rate of one word per second.

Please choose EITHER the 5 or 10 word list groups and circle the specific word list chosen for this test.

I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order. For Trials 2 & 3: I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before.

List	Alternate 5 word lists					Score (of 5)		
						Trial 1	Trial 2	Trial 3
A	Finger	Penny	Blanket	Lemon	Insect			
B	Candle	Paper	Sugar	Sandwich	Wagon			
C	Baby	Monkey	Perfume	Sunset	Iron			
D	Elbow	Apple	Carpet	Saddle	Bubble			
E	Jacket	Arrow	Pepper	Cotton	Movie			
F	Dollar	Honey	Mirror	Saddle	Anchor			
					Immediate Memory Score			of 15
					Time that last trial was completed			

List	Alternate 10 word lists					Score (of 10)		
						Trial 1	Trial 2	Trial 3
G	Finger	Penny	Blanket	Lemon	Insect			
	Candle	Paper	Sugar	Sandwich	Wagon			
H	Baby	Monkey	Perfume	Sunset	Iron			
	Elbow	Apple	Carpet	Saddle	Bubble			
I	Jacket	Arrow	Pepper	Cotton	Movie			
	Dollar	Honey	Mirror	Saddle	Anchor			
					Immediate Memory Score			of 30
					Time that last trial was completed			

Name: ______________________________

DOB: ______________________________

Address: ______________________________

ID number: ______________________________

Examiner: ______________________________

Date: ______________________________

CONCENTRATION

DIGITS BACKWARDS

Please circle the Digit list chosen (A, B, C, D, E, F). Administer at the rate of one digit per second reading DOWN the selected column.

I am going to read a string of numbers and when I am done, you repeat them back to me in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7.

Concentration Number Lists (circle one)					
List A	List B	List C			
5-2	4-1	4-9	Y	N	0
4-1	9-4	6-2	Y	N	1
4-9-3	5-2-6	1-4-2	Y	N	0
6-2-9	4-1-5	6-5-8	Y	N	1
3-8-1-4	1-7-9-5	6-8-3-1	Y	N	0
3-2-7-9	4-9-6-8	3-4-8-1	Y	N	1
6-2-9-7-1	4-8-5-2-7	4-9-1-5-3	Y	N	0
1-5-2-8-6	6-1-8-4-3	6-8-2-5-1	Y	N	1
7-1-8-4-6-2	8-3-1-9-6-4	3-7-6-5-1-9	Y	N	0
5-3-9-1-4-8	7-2-4-8-5-6	9-2-6-5-1-4	Y	N	1
List D	List E	List F			
2-7	9-2	7-8	Y	N	0
5-9	6-1	5-1	Y	N	1
7-8-2	3-8-2	2-7-1	Y	N	0
9-2-6	5-1-8	4-7-9	Y	N	1
4-1-8-3	2-7-9-3	1-6-8-3	Y	N	0
9-7-2-3	2-1-6-9-	3-9-2-4	Y	N	1
1-7-9-2-6	4-1-8-6-9	2-4-7-5-8	Y	N	0
4-1-7-5-2	9-4-1-7-5	8-3-9-6-4	Y	N	1
2-6-4-8-1-7	6-9-7-3-8-2	5-8-6-2-4-9	Y	N	0
8-4-1-9-3-5	4-2-7-3-9-8	3-1-7-8-2-6	Y	N	1
		Digits Score:			of 5

DAYS IN REVERSE ORDER

Now tell me the days of the week in reverse order. Start with the last day and go backward. So you'll say Sunday, Saturday. Go ahead.

Sunday - Saturday - Friday - Thursday - Wednesday - Tuesday - Monday	0 1
Days Score	of 1
Concentration Total Score (Digits + Days)	of 6

4

STEP 4: NEUROLOGICAL SCREEN

See the instruction sheet (page 7) for details of test administration and scoring of the tests.

Can the patient read aloud (e.g. symptom check-list) and follow instructions without difficulty?	Y	N
Does the patient have a full range of pain-free PASSIVE cervical spine movement?	Y	N
Without moving their head or neck, can the patient look side-to-side and up-and-down without double vision?	Y	N
Can the patient perform the finger nose coordination test normally?	Y	N
Can the patient perform tandem gait normally?	Y	N

BALANCE EXAMINATION

Modified Balance Error Scoring System (BESS) testing[9]

Which foot was tested (i.e. which is the non-dominant foot) ☐ Left ☐ Right

Testing surface (hard floor, field, etc.) ____________

Footwear (shoes, barefoot, braces, tape, etc.) ____________

Condition	Errors	
Double leg stance	of 10	
Single leg stance (non-dominant foot, 10-12 y/o only)	of 10	
Tandem stance (non-dominant foot at back)	of 10	
Total Errors	5-9 y/o of 20	10-12 y/o of 30

Name: ____________

DOB: ____________

Address: ____________

ID number: ____________

Examiner: ____________

Date: ____________

5

STEP 5: DELAYED RECALL:

The delayed recall should be performed after 5 minutes have elapsed since the end of the Immediate Recall section. Score 1 pt. for each correct response.

Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order.

Time Started ____________

Please record each word correctly recalled. Total score equals number of words recalled.

____

____

____

Total number of words recalled accurately: of 5 or of 10

6

STEP 6: DECISION

Domain	Date & time of assessment:		
Symptom number Child report (of 21) Parent report (of 21)			
Symptom severity score Child report (of 63) Parent report (of 63)			
Immediate memory	of 15 of 30	of 15 of 30	of 15 of 30
Concentration (of 6)			
Neuro exam	Normal Abnormal	Normal Abnormal	Normal Abnormal
Balance errors (5-9 y/o of 20) (10-12 y/o of 30)			
Delayed Recall	of 5 of 10	of 5 of 10	of 5 of 10

Date and time of injury: ____________

If the athlete is known to you prior to their injury, are they different from their usual self?

☐ **Yes** ☐ **No** ☐ **Unsure** ☐ **Not Applicable**

(If different, describe why in the clinical notes section)

Concussion Diagnosed?

☐ **Yes** ☐ **No** ☐ **Unsure** ☐ **Not Applicable**

If re-testing, has the athlete improved?

☐ **Yes** ☐ **No** ☐ **Unsure** ☐ **Not Applicable**

I am a physician or licensed healthcare professional and I have personally administered or supervised the administration of this Child SCAT5.

Signature: ____________

Name: ____________

Title: ____________

Registration number (if applicable): ____________

Date: ____________

SCORING ON THE CHILD SCAT5 SHOULD NOT BE USED AS A STAND-ALONE METHOD TO DIAGNOSE CONCUSSION, MEASURE RECOVERY OR MAKE DECISIONS ABOUT AN ATHLETE'S READINESS TO RETURN TO COMPETITION AFTER CONCUSSION.

For the Neurological Screen (page 5), if the child cannot read, ask him/her to describe what they see in this picture.

Name: ______________________

DOB: ______________________

Address: ______________________

ID number: ______________________

Examiner: ______________________

Date: ______________________

CLINICAL NOTES:

____

____

____

____

____

____

Concussion injury advice for the child and parents/carergivers

(To be given to the person monitoring the concussed child)

This child has had an injury to the head and needs to be carefully watched for the next 24 hours by a responsible adult.

If you notice any change in behavior, vomiting, dizziness, worsening headache, double vision or excessive drowsiness, please call an ambulance to take the child to hospital immediately.

Other important points:

Following concussion, the child should rest for at least 24 hours.

- The child should not use a computer, internet or play video games if these activities make symptoms worse.
- The child should not be given any medications, including pain killers, unless prescribed by a medical doctor.
- The child should not go back to school until symptoms are improving.
- The child should not go back to sport or play until a doctor gives permission.

Clinic phone number: ______________________

Patient's name: ______________________

Date / time of injury: ______________________

Date / time of medical review: ______________________

Healthcare Provider: ______________________

Contact details or stamp

Davis GA, *et al. Br J Sports Med* 2017;0:1–8. doi:10.1136/bjsports-2017-097492childscat5

INSTRUCTIONS

Words in *Italics* throughout the Child SCAT5 are the instructions given to the athlete by the clinician

Symptom Scale

In situations where the symptom scale is being completed after exercise, it should still be done in a resting state, at least 10 minutes post exercise.

At Baseline	On the day of injury	On all subsequent days
• The child is to complete the Child Report, according to how he/she feels today, and • The parent/carer is to complete the Parent Report according to how the child has been over the previous week.	• The child is to complete the Child Report, according to how he/she feels now. • If the parent is present, and has had time to assess the child on the day of injury, the parent completes the Parent Report according to how the child appears now.	• The child is to complete the Child Report, according to how he/she feels today, and • The parent/carer is to complete the Parent Report according to how the child has been over the previous 24 hours.

For Total number of symptoms, maximum possible is 21

For Symptom severity score, add all scores in table, maximum possible is 21 x 3 = 63

Standardized Assessment of Concussion Child Version (SAC-C)

Immediate Memory

Choose one of the 5-word lists. Then perform 3 trials of immediate memory using this list.

Complete all 3 trials regardless of score on previous trials.

"I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order." The words must be read at a rate of one word per second.

OPTION: The literature suggests that the Immediate Memory has a notable ceiling effect when a 5-word list is used. (In younger children, use the 5-word list). In settings where this ceiling is prominent the examiner may wish to make the task more difficult by incorporating two 5–word groups for a total of 10 words per trial. In this case the maximum score per trial is 10 with a total trial maximum of 30.

Trials 2 & 3 MUST be completed regardless of score on trial 1 & 2.

Trials 2 & 3: *"I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before."*

Score 1 pt. for each correct response. Total score equals sum across all 3 trials. Do NOT inform the athlete that delayed recall will be tested.

Concentration

Digits backward

Choose one column only, from List A, B, C, D, E or F, and administer those digits as follows:

"I am going to read you some numbers and when I am done, you say them back to me backwards, in reverse order of how I read them to you. For example, if I say 7-1, you would say 1-7."

If correct, circle "Y" for correct and go to next string length. If incorrect, circle "N" for the first string length and read trial 2 in the same string length. One point possible for each string length. Stop after incorrect on both trials (2 N's) in a string length. The digits should be read at the rate of one per second.

Days of the week in reverse order

"Now tell me the days of the week in reverse order. Start with Sunday and go backward. So you'll say Sunday, Saturday ... Go ahead"

1 pt. for entire sequence correct

Delayed Recall

The delayed recall should be performed after at least 5 minutes have elapsed since the end of the Immediate Recall section.

"Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order."

Circle each word correctly recalled. Total score equals number of words recalled.

Neurological Screen

Reading

The child is asked to read a paragraph of text from the instructions in the Child SCAT5. For children who can not read, they are asked to describe what they see in a photograph or picture, such as that on page 6 of the Child SCAT5.

Modified Balance Error Scoring System (mBESS)[5] testing

These instructions are to be read by the person administering the Child SCAT5, and each balance task should be demonstrated to the child. The child should then be asked to copy what the examiner demonstrated.

Each of 20-second trial/stance is scored by counting the number of errors. The This balance testing is based on a modified version of the Balance Error Scoring System (BESS)[5].

A stopwatch or watch with a second hand is required for this testing.

"I am now going to test your balance. Please take your shoes off, roll up your pants above your ankle (if applicable), and remove any ankle taping (if applicable). This test will consist of two different parts."

OPTION: For further assessment, the same 3 stances can be performed on a surface of medium density foam (e.g., approximately 50cm x 40cm x 6cm).

(a) Double leg stance:

The first stance is standing with the feet together with hands on hips and with eyes closed. The child should try to maintain stability in that position for 20 seconds. You should inform the child that you will be counting the number of times the child moves out of this position. You should start timing when the child is set and the eyes are closed.

(b) Tandem stance:

Instruct or show the child how to stand heel-to-toe with the non-dominant foot in the back. Weight should be evenly distributed across both feet. Again, the child should try to maintain stability for 20 seconds with hands on hips and eyes closed. You should inform the child that you will be counting the number of times the child moves out of this position. If the child stumbles out of this position, instruct him/her to open the eyes and return to the start position and continue balancing. You should start timing when the child is set and the eyes are closed.

(c) Single leg stance (10-12 year olds only):

"If you were to kick a ball, which foot would you use? [This will be the dominant foot] *Now stand on your other foot. You should bend your other leg and hold it up (show the child). Again, try to stay in that position for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you move out of this position, open your eyes and return to the start position and keep balancing. I will start timing when you are set and have closed your eyes."*

Balance testing – types of errors

1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into > 30 degrees abduction
5. Lifting forefoot or heel
6. Remaining out of test position > 5 sec

Each of the 20-second trials is scored by counting the errors, or deviations from the proper stance, accumulated by the child. The examiner will begin counting errors only after the child has assumed the proper start position. The modified BESS is calculated by adding one error point for each error during the 20-second tests. The maximum total number of errors for any single condition is 10. If a child commits multiple errors simultaneously, only one error is recorded but the child should quickly return to the testing position, and counting should resume once subject is set. Children who are unable to maintain the testing procedure for a minimum of five seconds at the start are assigned the highest possible score, ten, for that testing condition.

Tandem Gait

Instruction for the examiner - Demonstrate the following to the child:

The child is instructed to stand with their feet together behind a starting line (the test is best done with footwear removed). Then, they walk in a forward direction as quickly and as accurately as possible along a 38mm wide (sports tape), 3 metre line with an alternate foot heel-to-toe gait ensuring that they approximate their heel and toe on each step. Once they cross the end of the 3m line, they turn 180 degrees and return to the starting point using the same gait. Children fail the test if they step off the line, have a separation between their heel and toe, or if they touch or grab the examiner or an object.

Finger to Nose

The tester should demonstrate it to the child.

"I am going to test your coordination now. Please sit comfortably on the chair with your eyes open and your arm (either right or left) outstretched (shoulder flexed to 90 degrees and elbow and fingers extended). When I give a start signal, I would like you to perform five successive finger to nose repetitions using your index finger to touch the tip of the nose as quickly and as accurately as possible."

Scoring: 5 correct repetitions in < 4 seconds = 1

Note for testers: Children fail the test if they do not touch their nose, do not fully extend their elbow or do not perform five repetitions.

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CONCUSSION INFORMATION

If you think you or a teammate has a concussion, tell your coach/trainer/ parent right away so that you can be taken out of the game. You or your teammate should be seen by a doctor as soon as possible. YOU OR YOUR TEAMMATE SHOULD NOT GO BACK TO PLAY/SPORT THAT DAY.

Signs to watch for

Problems can happen over the first 24-48 hours. You or your teammate should not be left alone and must go to a hospital right away if any of the following happens:

- New headache, or headache gets worse
- Neck pain that gets worse
- Becomes sleepy/ drowsy or can't be woken up
- Cannot recognise people or places
- Feeling sick to your stomach or vomiting
- Acting weird/strange, seems/feels confused, or is irritable
- Has any seizures (arms and/or legs jerk uncontrollably)
- Has weakness, numbness or tingling (arms, legs or face)
- Is unsteady walking or standing
- Talking is slurred
- Cannot understand what someone is saying or directions

Consult your physician or licensed healthcare professional after a suspected concussion. Remember, it is better to be safe.

Graduated Return to Sport Strategy

After a concussion, the child should rest physically and mentally for a few days to allow symptoms to get better. In most cases, after a few days of rest, they can gradually increase their daily activity level as long as symptoms don't get worse. Once they are able to do their usual daily activities without symptoms, the child should gradually increase exercise in steps, guided by the healthcare professional (see below).

The athlete should not return to play/sport the day of injury.

NOTE: An initial period of a few days of both cognitive ("thinking") and physical rest is recommended before beginning the Return to Sport progression.

Exercise step	Functional exercise at each step	Goal of each step
1. Symptom-limited activity	Daily activities that do not provoke symptoms.	Gradual reintroduction of work/school activities.
2. Light aerobic exercise	Walking or stationary cycling at slow to medium pace. No resistance training.	Increase heart rate.
3. Sport-specific exercise	Running or skating drills. No head impact activities.	Add movement.
4. Non-contact training drills	Harder training drills, e.g., passing drills. May start progressive resistance training.	Exercise, coordination, and increased thinking.
5. Full contact practice	Following medical clearance, participate in normal training activities.	Restore confidence and assess functional skills by coaching staff.
6. Return to play/sport	Normal game play.	

There should be at least 24 hours (or longer) for each step of the progression. If any symptoms worsen while exercising, the athlete should go back to the previous step. Resistance training should be added only in the later stages (Stage 3 or 4 at the earliest). The athlete should not return to sport until the concussion symptoms have gone, they have successfully returned to full school/learning activities, and the healthcare professional has given the child written permission to return to sport.

If the child has symptoms for more than a month, they should ask to be referred to a healthcare professional who is an expert in the management of concussion.

Graduated Return to School Strategy

Concussion may affect the ability to learn at school. The child may need to miss a few days of school after a concussion, but the child's doctor should help them get back to school after a few days. When going back to school, some children may need to go back gradually and may need to have some changes made to their schedule so that concussion symptoms don't get a lot worse. If a particular activity makes symptoms a lot worse, then the child should stop that activity and rest until symptoms get better. To make sure that the child can get back to school without problems, it is important that the health care provider, parents/caregivers and teachers talk to each other so that everyone knows what the plan is for the child to go back to school.

Note: If mental activity does not cause any symptoms, the child may be able to return to school part-time without doing school activities at home first.

Mental Activity	Activity at each step	Goal of each step
1. Daily activities that do not give the child symptoms	Typical activities that the child does during the day as long as they do not increase symptoms (e.g. reading, texting, screen time). Start with 5-15 minutes at a time and gradually build up.	Gradual return to typical activities.
2. School activities	Homework, reading or other cognitive activities outside of the classroom.	Increase tolerance to cognitive work.
3. Return to school part-time	Gradual introduction of schoolwork. May need to start with a partial school day or with increased breaks during the day.	Increase academic activities.
4. Return to school full-time	Gradually progress school activities until a full day can be tolerated.	Return to full academic activities and catch up on missed work.

If the child continues to have symptoms with mental activity, some other things that can be done to help with return to school may include:

- Starting school later, only going for half days, or going only to certain classes
- More time to finish assignments/tests
- Quiet room to finish assignments/tests
- Not going to noisy areas like the cafeteria, assembly halls, sporting events, music class, shop class, etc.
- Taking lots of breaks during class, homework, tests
- No more than one exam/day
- Shorter assignments
- Repetition/memory cues
- Use of a student helper/tutor
- Reassurance from teachers that the child will be supported while getting better

The child should not go back to sports until they are back to school/ learning, without symptoms getting significantly worse and no longer needing any changes to their schedule.

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Biography

Patricia M. Kelshaw is from Temple Hills, MD and graduated from Elizabeth Seton High School in 2010. She moved to Virginia in 2014 to attend George Mason University where she pursued her Bachelors, Masters, and Doctorate degrees.