Pediatric Sport-related Concussion: Recommendations From the Amsterdam Consensus Statement 2023

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The 6th International Consensus Conference on Concussion in Sport, Amsterdam 2022, addressed sport-related concussion (SRC) in adults, adolescents, and children. We highlight the updated evidence-base and recommendations regarding SRC in children (5–12 years) and adolescents (13–18 years). Prevention strategies demonstrate lower SRC rates with mouthguard use, policy disallowing bodychecking in ice hockey, and neuromuscular training in adolescent rugby. The Sport Concussion Assessment Tools (SCAT) demonstrate robustness with the parent and child symptom scales, with the best diagnostic discrimination within the first 72 hours postinjury. Subacute evaluation (>72 hours) requires a multimodal tool incorporating symptom scales, balance measures, cognitive, oculomotor and vestibular, mental health, and sleep assessment, to which end the Sport Concussion Office Assessment Tools (SCOAT6 [13+] and Child SCOAT6 [8–12]) were developed. Rather than strict rest, early return to light physical activity and reduced screen time facilitate recovery. Cervicovestibular rehabilitation is recommended for adolescents with dizziness, neck pain, and/or headaches for greater than 10 days. Active rehabilitation and collaborative care for adolescents with persisting symptoms for more than 30 days may decrease symptoms. No tests and measures other than standardized and validated symptom rating scales are valid for diagnosing persisting symptoms after concussion. Fluid and imaging biomarkers currently have limited clinical utility in diagnosing or assessing recovery from SRC. Improved paradigms for return to school were developed. The variable nature of disability and differences in evaluating para athletes and those of diverse ethnicity, sex, and gender are discussed, as are ethical considerations and future directions in pediatric SRC research.

International sports organizations have worked collaboratively with the Concussion in Sport Group to hold quadrennial consensus conferences and produce a summary or consensus statement[1–6] from each meeting that summarizes the evidence and makes recommendations regarding sport-related concussion (SRC) in adults, adolescents, and children. A core component informing the last 2 conferences and consensus statements has been a series of systematic reviews published with the Consensus Statement. In Berlin 2016, 1 of the 12 systematic reviews was

abstract

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To cite: Davis GA, Schneider KJ, Anderson V, et al. Pediatric Sport-related Concussion: Recommendations From the Amsterdam Consensus Statement 2023. *Pediatrics.* 2024; 153(1):e2023063489

dedicated to pediatric concussion.[7] At the 6th International Consensus Conference on Concussion in Sport, Amsterdam 2022, the scientific committee incorporated pediatrics into each systematic review, rather than produce a stand-alone pediatric systematic review. In addition, pediatric concussion was included as a separate section in the Consensus Statement. Multiple clinicians and scientists with experience in pediatric concussion were coauthors of each systematic review to ensure that pediatrics was adequately addressed. Each review extracted data specific to children (<13 years) and adolescents (13 to <18 years), resulting in significant pediatric data being acquired. This paper provides a dedicated pediatric publication consolidating each component of the Amsterdam Consensus Statement pertaining to child and adolescent SRC, informed by the systematic reviews.

The scientifically rigorous consensus methodology and details on the systematic reviews and associated processes are described in detail by Schneider et al.[8] The definition of SRC was updated as part of the Amsterdam process and is described in the Appendix 1.[9]

PEDIATRIC FINDINGS FROM THE SYTEMATIC REVIEWS

Prevention Strategies and Modifiable Risk Factors for Sport-related Concussions and Head Impacts: A Systematic Review and Meta-analysis[10]

Adolescents were the target populations in over 50% of the published studies evaluating SRC prevention strategies and/or modifiable risk factors,[10] with few focused on the 5 to 12 year age group alone.[6] Concussion prevention strategies for children and adolescents highlight the role of personal protective equipment, policy and/or rule changes, training strategies, and management strategies targeting recurrent concussion.

Protective Equipment

Studies evaluating headgear (as opposed to helmets) in football (soccer), Australian football, and Rugby Union (rugby) report mixed findings regarding their protective effect against concussion. When data were combined in a meta-analysis across adolescent studies in rugby, soccer, and lacrosse, headgear was not significantly associated with SRC rates (IRR [incidence rate ratio] = 0.74; 95% confidence interval [CI]: 0.5–1.09).[10,11] By sport, headgear use was associated with lower SRC rates in the meta-analysis combining 2 soccer studies (IRR = 0.64; 95% CI: 0.44–0.92)[10,12,13]; however, further evaluation in larger studies evaluating different headgear design and materials is necessary to inform any recommendation. In helmeted adolescent collision sports, evidence indicates that secure helmet fit may reduce concussion rates and severity in ice hockey and American football.[14,15] The protective effect of mouthguards has been demonstrated in adolescent ice hockey (IRR = 0.75; 95% CI: 0.64–0.88).[16] Protective eyewear in adolescent field hockey reduced head and face injuries, but did not reduce SRC rates (IRR = 0.96; 95% CI: 0.57–1.59; IRR = 0.77; 95% CI: 0.58–1.02).[17,18]

Policy or Rule Changes

A combined 58% lower concussion rate was identified where policy disallowed bodychecking in child and adolescent ice hockey leagues (IRR = 0.42; 95% CI: 0.33–0.53).[10] Further, number of years of body checking experience was not protective for concussion,[19] thus disallowing body checking for children and most levels of adolescent ice hockey is recommended. Restricting the frequency and/or duration of collision practices in adolescents in American football reduced head contact (IRR = 0.22; 95% CI: 0.21–0.23)[20] and practice-related concussion rates (IRR = 0.44; 95% CI: 0.25–0.75).[21] The positive effect of limiting body checking in ice hockey and restricting contact practice in American football in reducing SRC rates may be a consideration across a range of adolescent collision sports.

Training Strategies

On-field neuromuscular training (NMT) warm-up strategies (eg, balance, strength, agility) have been demonstrated to be effective in reducing injuries across multiple adolescent team sports.[22] When compared with the standard practice warm-up, NMT inclusive of a neck strengthening component was associated with a 59% lower SRC rate in school-boy (ages 14–18) rugby players (risk ratio = 0.41; 90% CI: 0.17–0.99) when completed ≥3 times per week.[23] The effect of NMT programs for specifically reducing concussion rates has not been assessed in other sports and a focus on evaluating specific NMT components for concussion prevention is necessary in children and adolescents.

Concussion Management

Evidence supports implementation of concussion laws (eg, mandatory removal from play, requirements to receive clearance to return to play from a licensed health care professional (HCP), and education of coaches, parents, and athletes) to reduce recurrent concussions in adolescent sports.[24,25]

Acute Evaluation of Sport-related Concussion and Implications for the Sport Concussion Assessment Tool (SCAT6) for Adults, Adolescents, and Children: A Systematic Review[26]

Examination of pediatric age groups (5–12, 13–18 years) at the acute stage (<72 hours) of concussion assessment revealed a significant disparity in the literature. For children ages 5 to 12 years, only 5 eligible studies[27–31] examined Child SCAT tool utility, with none SRC-focused. Specifically, the cognitive measures of the Child SCAT demonstrated low test-retest stability,[28] implying limited

clinical utility, and there was no comparison of injured versus uninjured children. More robust psychometric characteristics are reported for the parent and child symptom scales,[31] with solid evidence of internal consistency and stability over time,[27,28] as well as strong differentiation of concussed athletes from controls.[31] The modified Balance Error Scoring System balance examination exhibits variability,[28,32] with promise for improved reliability with more systematic training methods. A significantly greater body of literature supports the discriminatory ability of the SCAT tools in adolescents within the first 72 hours of injury, with its utility diminishing by 7 days.

Routine, across-the-board, mandatory baseline testing was not recommended in children because of rapid developmental changes through childhood and adolescence, although it could be considered for older athletes and parasport athletes in competitive sport settings if resources permit.[8] If baseline testing is conducted, it requires (1) appropriate resources (ie, trained personnel) to conduct the testing effectively, and (2) use of measures with robust appropriate psychometrics (ie, reliable change metrics) to demonstrate meaningful clinical change for the individual.

A significant need exists for developmentally appropriate concussion tools spanning the full age range of children and adolescents.[33,34] Additional recommendations include collecting more diversified, global normative data for all ages, including subgroups with developmental and psychiatric diagnoses. Focused efforts are needed to study tools in the under-12 age group in SRC cases and controls and to expand settings to emergency departments and primary care for younger age samples. Modifying cognitive (eg, timed components) and balance measures (eg, dual task) can enhance their diagnostic sensitivity.

Beyond Acute Concussion Assessment to Office Management: A Systematic Review Informing the Development of a Sport Concussion Office Assessment Tool (SCOAT6) for Adults and Children[35]

Several assessment tools have been used to diagnose SRC in children and adolescents, including symptom scales, balance measures, cognitive tests, and oculomotor and vestibular tests. Symptom scales reliably distinguished between concussed and nonconcussed athletes in the acute and subacute (3–30 days) periods post-SRC.[36–42] Balance assessment with the modified Balance Error Scoring System significantly differentiated between concussed adolescent athletes and controls in the subacute period, with more errors in concussed athletes,[43] and complex tandem gait assessments elicited significantly more sway or errors in concussed subjects compared with controls in the subacute period.[43] Concussed athletes performed tandem gait slower than controls for both single-task and dual-task conditions and demonstrated worse dual-task cognitive accuracy.[44–46] Similarly, Vestibular Ocular Motor Screening components were significantly different in concussed adolescents compared with baseline measures and with healthy controls 0 to 14 days postinjury.[36,47–49] The Visio-Vestibular Examination assesses visio-vestibular function, including complex tandem gait, and has been validated for use in the diagnosis of concussion in children.[50]

Two new office assessment tools were developed as part of the Amsterdam consensus to assist in the assessment of children and adolescents with concussion in the subacute period. The Sport Concussion Office Assessment Tool (SCOAT6) was designed for ages 13 years and older and the Child SCOAT6 was developed for children aged 8 to 12 years.[51,52] As with the SCAT6 and Child SCAT6, these tools are designed for use by HCPs.

Rest and Exercise Early After Sport-related Concussion: A Systematic Review and Meta-analysis[53]

This review synthesized the best evidence on the risks and benefits of early physical activity (PA), prescribed aerobic exercise treatment, rest, cognitive activity, and sleep during the first 14 days after SRC. Most papers reviewed included the pediatric age group, and although some included children ≤12 years among the larger cohort, the majority assessed adolescents and young adults. There was no evidence that strict physical and cognitive rest until complete symptom resolution (so called "cocooning") facilitated recovery from SRC. In a meta-analysis, PA and prescribed individualized exercise treatment (based on systematic exercise testing) improved recovery by a mean of 4.64 days (95% CI 6.69–2.59).[53] During the first 2 days after SRC, early return to light PA (eg, walking) and reduced screen time followed by prescribed aerobic exercise treatment (days 2–14) safely facilitated recovery, whereas sleep disturbance was associated with slower recovery.[53] Prescribed aerobic exercise treatment within 14 days of SRC also significantly reduced the incidence of concussive symptoms persisting beyond 30 days and the associated reduced quality of life and learning difficulties in school. Aerobic exercise was found to also benefit those with persisting symptoms beyond 1 month. The data confirmed that brief, mild concussion symptom exacerbation (ie, no more than a 2-point increase on a 0–10 scale when compared with the preactivity level for no more than an hour) during physical or cognitive activity is not harmful and does not delay recovery.[53] Despite current evidence predominantly involving adolescents, evidence suggests that strict rest until symptom resolution may delay recovery in children.[53–57] As such, early PA and subsymptom threshold aerobic exercise in children should align with the paradigm in adolescents until age-specific data become available.

Targeted Interventions and Their Effect on Recovery in Children, Adolescents, and Adults Who Have Sustained a Sport-related Concussion - A Systematic Review[58]

Much of the literature evaluating rehabilitation strategies after SRC included adults and adolescents, with few studies including children. Light aerobic activity should be started as soon as 2 days after SRC. The athlete does not need to be "cleared" for subsymptom threshold aerobic exercise. Cervicovestibular rehabilitation is recommended for adolescents with dizziness, neck pain, and/or headaches for greater than 10 days, and may decrease time to medical clearance for return to sport.[59,60] Adolescents experiencing dizziness for more than 5 days may benefit from vestibular rehabilitation.[61] Active rehabilitation and collaborative care for adolescents with persisting symptoms for more than 30 days may decrease symptoms.[62]

There is limited literature evaluating rehabilitation strategies in children aged 5 to 12 years with SRC and those studies that did include children often only included 11- to 12-year-olds. Although more research has evaluated rehabilitation in adolescents, an understanding of differences in response to rehabilitation by age is limited since most studies crossed age groups. Most studies did not consider sex or gender. In addition, other research may be available across all types of mild traumatic brain injury arising from mechanisms of injury other than sport that identifies additional types of rehabilitation that could be of benefit and were not captured in this SRC-focused review.

What Tests and Measures Accurately Diagnose Persisting Postconcussive Symptoms in Children, Adolescents, and Adults Following Sport-related Concussion? A Systematic Review[63]

Up to 30% of children and adolescents experience persisting symptoms after concussion, defined as symptoms lasting for 4 weeks or longer after SRC. Of 26 studies in the systematic review, 8 involved children and adolescents only, whereas 11 bridged both pediatric and adult ages, most often including both adolescents and adults. The studies used a wide variety of measures and tests to investigate persisting symptoms, but none were designed to assess their ability to accurately diagnose persisting symptoms.

Neuroimaging studies reported subtle differences in white matter microstructure, brain activation during memory and balance tasks, and altered cerebral blood flow in children with persisting symptoms. Other measures in a variety of domains may support the diagnosis of persisting symptoms, especially the use of rating scales to demonstrate associated mood problems and lower quality of life.[63]

Overall, the evidence supporting the use of specific tests or measures for the differential diagnosis of persisting symptoms was deemed to be inconsistent, of limited quality (ie, mostly high risk of bias), and insufficient to determine how the differential diagnosis of persisting symptoms might differ among children, adolescents, and adults. Pediatric samples were reasonably balanced for sex, although gender, race, ethnicity, and other social determinants were usually not reported.

Persisting symptoms can be assessed using clinical expertise and standardized and validated symptom rating scales, but evidence-based recommendations regarding the use of other specific tests or measures in the clinical diagnosis of persisting symptoms are not possible currently. Future research is needed to determine which tests or measures differentiate children with and without persisting symptoms after SRC, preferably based on large prospective cohort studies with longitudinal follow-up, limited attrition, and common data elements.

Role of Biomarkers and Emerging Technologies in Defining and Assessing Neurobiological Recovery After Sport-related Concussion: A Systematic Review[64]

Limited pediatric-specific data were available. When compared with adults, the influences of puberty and brain development in children and adolescents may result in differences in the performance and utility of fluid biomarkers and emerging technologies for the purpose of diagnosing SRC and assessing neurobiological recovery.

Findings regarding objective diagnosis of SRC were similar to adults. Although group differences were demonstrated for several objective tools between young athletes with and without SRC,[64] the evidence is insufficient for recommending their use in clinical practice.

For monitoring recovery, studies on fluid biomarkers, advanced neuroimaging, and emerging technologies showed group differences at both symptom resolution and/or medical clearance, demonstrating that underlying physiologic effects of SRC may persist beyond symptom resolution and apparent clinical recovery.[64] However, their role in guiding clinical management at the individual level remains unclear.

Research characterizing the genetic aspects of concussion and recovery remains limited, with no studies including participants <18 years. Study results remain difficult to compare given substantial heterogeneity in study designs, methodologies, and data elements across domains.

Clinical Recovery From Concussion – Return to School and Sport: A Systematic Review and Meta-analysis[65]

The majority of children and adolescents who sustain SRC demonstrate complete resolution of concussion-related symptoms within 1 month.[66–69] The most consistent predictor of a longer recovery is a greater initial symptom burden (number and severity).[70–73] Other factors contributing to longer recovery times included continued play postinjury[74]; delayed presentation to a medical provider[75]; migraine history in females[76]; very high physical and

cognitive activity levels after injury[77,78]; and prolonged cognitive rest.[79–81]

The majority of children and adolescents return to school by 10 days without academic supports.[69,71,77,82] Longer return to school was associated with greater initial symptom severity[70–73] and low activity levels after injury.[77] Students experiencing difficulty with return to school may find the consensus strategy helpful,[65] in addition to receiving symptom-specific academic supports that encompass environmental, physical, curriculum, and testing factors.[83]

Most children and adolescents are able to return to sport following SRC within 1 month.[39,69,84] A higher symptom burden (number of and severity of symptoms) after concussion is associated with a longer return to sport, as well as the need for academic support.[69,83] Children and adolescents can safely follow the consensus return to sport strategy.[65] A qualified HCP should monitor the return to sport process, with medical clearance before return to any activities with risk of contact, collision, or fall.

When Should an Athlete Retire or Discontinue Participating in Contact or Collision Sports After Sport-related Concussion? A Systematic Review[85]

Although focused mostly on career-ending decisions related to SRC in adults, this systematic review also discussed retirement in children and adolescents participating in contact and collision sport. Children and adolescent athletes progressing to the next age group level in contact or collision sports, or to higher levels of competition, including participation in elite pathway programs and/or open-age competitions, may be at greater risk of concussion with increased training loads, exposure to players of a larger size, and higher velocity of impacts.[85]

The cognitively immature child or adolescent athlete may not yet be capable of adequately understanding the relative risks and benefits of participating in contact or collision sports. Parents and guardians may not be unanimous in their recommendations or influenced by multiple factors, including cultural and socioeconomic background, expectations for the child's future professional sports capabilities, vicarious benefits from the child's sporting achievements, and anxieties.

Decisions on when to cease participation in contact or collision sports are typically complex and multifaceted. The systematic review examined the contraindications to children and adolescent athletes entering or continuing with contact or collision sports[85] and, as none of the studies directly examined the issue of retirement and/or discontinuation from contact or collision sports, included studies that assessed factors associated with (1) *prolonged recovery* after SRC and/or (2) *increased risk of concussion*. Results across studies were heterogenous, and although not specific to children, the most consistent factors associated with *prolonged recovery* were longer time to presentation, total number and/or severity of symptoms at initial presentation, sleep disturbance, and symptom provocation with vestibular ocular motor testing and, for *increased risk of concussion*, history of previous concussion was the most consistent risk factor. Only 2 studies specifically examined children and only 14 examined adolescents. Major limitations of the studies included significant heterogeneity in study methodologies, definitions of "prolonged symptoms," age distribution, and selection bias with few high-quality cohort studies.

Limitations Common to All Pediatric Systematic Reviews

Limitations common to all the systematic reviews included a lack of studies in the 5 to 12-year age group, results not being stratified by age in studies with mixed age populations, and potential selection bias in studies with patients presenting to specialty clinic settings. Additionally, many studies of children with concussion were excluded from the systematic reviews because they did not meet the criteria of majority SRC. Many studies included predominantly male athletes and most studies were from North America, limiting generalizability. Definitions of clinical recovery varied across studies, making comparisons difficult. Increased media attention, awareness of concussion, and concurrent concussion education programs may have influenced concussion reporting rates for children, adolescents, and their parents, and may have affected study results when evaluating concussion prevention strategies longitudinally.

Para Sports

Globally, approximately 10% of children and adolescents are estimated to have a disability,[86] and participation in physical activity and sport within this population is on the rise.[87] Several of the more common types of developmental and childhood-onset disability (eg, spina bifida, cerebral palsy) impact functioning of the central nervous system and likely lead to differences in how an individual is impacted by concussion. Given the distinct paucity of research evaluating the concussion experience in the pediatric para athlete, the Concussion in Para Sport Group developed a Position Statement[88] to summarize the available literature, as well as expert opinion, related to the recognition, assessment, and management of concussion in the para athlete across the lifespan, inclusive of the pediatric athlete.

The Concussion in Para Sport Group Statement noted that children and adolescents with disabilities may uniquely benefit from preseason baseline testing given the variable nature of their disability and thus, atypical presenting concussion signs or symptoms. Additionally, individuals with a history of central nervous system injury may require more careful

evaluation and an extended period of initial rest after SRC. Testing for concussion may require modifications, such as use of arm ergometry, as opposed to a treadmill or stationary bike, with return to sport protocols tailored to include use of the individual's personal adaptive equipment. The most commonly used SRC assessment tools (eg, Child SCAT) are not validated in the pediatric para athlete population, who require an even more individualized approach. More research is needed to understand the impact of concussion on children and adolescents with disabilities.

Ethics

The application of the extant child and adolescent research in SRC to clinical management is fraught with conceptual, methodological, and translational challenges that have significant ethical import. The concept of childhood is itself vague and contested and has no unequivocal legal or moral border with adolescence, which in turn has no absolute border with adulthood.[89] The borders are influenced by a range of biopsychosocial factors that are not subject to universal agreement. In most western medical contexts, distinctions between children, adolescent, and adult populations are mostly artificial or arbitrary.[90] More specifically, sport medicine professionals often work with a binary pediatric or adult distinction. However, evidence for brain developmental changes in childhood indicate the important difference between children (≤12 years) and adolescents (≥12 years).[91] Although there is more SRC research for later adolescents that can help inform shared-decision making than for early adolescents, there is greater ambiguity around their competence to consent to research and treatment. Conversely, there is greater clarity on ethical processes with children. Due to children's lack of, or merely emerging, capacity, and their physiologic vulnerability because of developmental considerations, parents or other proxy decision-makers are therefore required on ethical and legal grounds. Paradoxically, less specific research is available on children with SRC to guide informed decisions.[92]

Additionally, there is a general paucity of childhood clinical trials,[93] to the point where they have been described as "therapeutic orphans" in research.[94] The lack of clinical trials is mirrored both in pediatric medical ethics research[95] and in childhood sport medicine research, as highlighted by the Concussion Consensus Statement.[6] Indeed, the empirical research and extant recommendations pertaining to pediatric SRC in the systematic reviews conducted as part of the Amsterdam consensus are dominated by findings from adolescents, in some cases predominantly focused on males (eg, prevention and acute detection of concussion).[10,26] However, a substantial body of relevant research on children, as well as adolescents, is available that did not meet the methodological requirement to focus primarily on SRC, as opposed to concussion from all causes, as reflected in the Amsterdam Consensus methodology.[8,96–105] Moreover, evidence-based clinical practice guidelines for pediatric concussion are available for consultation. These points serve as a general ethical precaution on the interpretation of the empirical research relevant to nonadult populations.

A general ethical foundation is that clinicians must work from what evidence arises in both sport and nonsport contexts to inform clinical care. Thus, in the absence of universally agreed principles to guide application, it is frequent to resort to a focus on good (ie, reasoned, transparent, and accountable) processes. In the medical ethics lexicon, this is referred to as Accountability for Reasonableness.[106] Thus, with concussed pediatric patients, good practice may simply demand a transparent process whereby clinicians, using the information cited in the Consensus Statement, including guidance offered for tools such as the Child SCAT6[107] and Child SCOAT6,[108] and using other relevant research with appropriate inferential justification, can satisfy Accountability for Reasonableness.[106] This would be underpinned by a broadly precautionary approach[109] given children's and adolescent's inherent status as vulnerable populations with protected characteristics (ie, according to the differing global contexts of care, this may include liberal notions such as the right of children and adolescents to an open future).[110,111] This approach must be balanced with careful considerations of the notable health-related benefits of sport and physical activity. In particular, sports that modify training and competition based on age and developmental considerations[112] may be considered as better satisfying the precautionary approach than those that do not. Notwithstanding these accommodations, the importance of brain health and development in children will require greater than normal precautions in relation to sports regulation and practices. In that regard, children and adolescents require consideration of a return-to-learn strategy, as detailed in the Consensus Statement[6] and the systematic review informing it,[65] which should take precedence over return to sport.

Tools

The Amsterdam process included updates of the Concussion Recognition Tool (CRT6)[113,114] and the Sport Concussion Assessment Tools (SCAT6 and Child SCAT6),[107,115–117] and development of a new set of tools, the Sport Concussion Office Assessment Tool (SCOAT6 and Child SCOAT6),[51,52,108,118] (Fig 1), the evidence for which was discussed earlier. The CRT6 is designed for the layperson to recognize concussion symptoms and signs in children, adolescents, and adults and provides advice regarding removal from play, immediate management, and "red flags." Widespread use of CRT6 by parents, coaches, teachers, and referees involved at any level with pediatric athletes across all sports is encouraged.

The SCAT6 (adolescents and adults)[115] and Child SCAT6[117] (ages 8–12 years) tools have been developed for HCPs for use in the acute period postconcussion.

FIGURE 1
The Tools developed for use by the lay person (CRT6), and for health care professionals in the acute period (SCAT6 and Child SCAT6) and subacute period (SCOAT6 and Child SCOAT6). Free downloads of all the tools available at https://bjsm.bmj.com/content/57/11.

The SCOAT6[52] (13+ years) and Child SCOAT6[51] (8–12 years) tools were developed for HCPs for subacute assessment in the office environment and promote a multimodal assessment of the concussed athlete, including detailed clinical history, symptom evaluation, cognitive tests, orthostatic vital signs, cervical spine assessment, neurologic examination, balance assessment, timed tandem gait, complex tandem gait, dual-task tandem gait, visio-vestibular examination, sleep assessment, mental health screen, and graded aerobic exercise tests. The Child SCOAT6 includes age-appropriate versions of each of the test components. Specific additions or changes relative to the Child SCOAT6 include:

- Additional symptoms for child and parent report that capture multiple subacute domains.
- An age-appropriate measure of cognitive reaction time (ie, the Symbol Digit Modalities Test).
- Validated pediatric measures of (i) orthostatic tachycardia, (ii) orthostatic intolerance, (iii) visio-vestibular function, and (iv) child mental health and sleep questionnaires.

The tools also include summary tables for return-to-school and return-to-sport strategies, with additional explanatory notes.

All the tools are available as free downloads.[51,52,114,115,117,119]

Future Directions

The systematic reviews highlight the paucity of age-specific research in children and the need for more research in the 5 to 12-year age group, particularly in children <8 years, in all areas of SRC. Future research evaluating concussion and head impact prevention strategies targeting sport-specific equipment, rule changes, training strategies, and management strategies is needed in children, and especially in girls. Other required research includes patient reported outcomes, specific objective outcomes, and operationally defined functional measures of recovery; comparisons of general versus targeted treatments; recording of specific treatment subcomponents, timing, frequency, duration, or intensity and combinations of treatments; and measurement of factors such as sex, gender, ethnicity, socioeconomic status, and para athlete-specific considerations. Additional research evaluating return to school and academic supports after SRC is needed, as well as studies of modifying factors for recovery and for returning to school and sport, and modifying factors in younger age groups, including mechanisms of injury. Accomplishing this goal may necessitate changing how SRC is defined and recognized in younger age groups. Studies that include mixed age populations should stratify results by age and sex whenever possible. Future research must be methodologically sound, including standardized definitions and evidence-based metrics. The Child SCAT6 and Child SCOAT6 require research and validation in different clinical and cultural settings.

CONCLUSIONS

The 6th International Consensus Conference on Concussion in Sport, the associated systematic reviews, and the Consensus Statement have provided significant updates on SRC in athletes of all ages. This paper highlights the key findings pertaining to children and adolescents, including prevention, sideline screening, office assessment, rest and exercise, rehabilitation, persisting symptoms, recovery, return to school and to sport, retirement, the para sport athlete, and ethical considerations, in addition to the important tools for the acute and subacute periods, with versions of each relevant to the adolescent and child. The clinical care of concussion in children and adolescents has improved significantly since the initial Concussion in Sport Group meeting at the turn of this century; however, the paucity of studies in younger children and lack of studies that are stratified by age to better understand the specific modifications to concussion care in pediatric athletes indicates the urgent requirement for more SRC research dedicated to children.

ABBREVIATIONS

CRT6: Concussion Recognition Tool 6
HCP: health care professional
NMT: neuromuscular training
PA: physical activity
SCAT6: Sport Concussion Assessment Tool 6
SCOAT6: Sport Concussion Office Assessment Tool 6
SRC: sport-related concussion

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Dr Davis conceptualized and designed the study, and all authors contributed to drafting, and critically reviewing and revising, the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

The guidelines and recommendations in this article are not American Academy of Pediatrics policy, and publication herein does not imply endorsement.

DOI: https://doi.org/10.1542/peds.2023-063489

Accepted for publication Sep 7, 2023

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FUNDING: No external funding, however, the Organising Committee for the Amsterdam Consensus Conference provided logistical support for the conference and an educational grant for the administrative aspects of the work.

CONFLICT OF INTEREST DISCLOSURES: Gavin A. Davis is a member of the Scientific Committee of the 6th International Conference on Concussion in Sport; an honorary member of the AFL Concussion Scientific Committee; Section Editor, Sport and Rehabilitation, Neurosurgery, and has attended meetings organised by sport organisations including NFL, NRL, IIHF, IOC, and FIFA; however, has not received any payment, research funding, nor any other monies from these groups other than for travel costs. Kathryn J. Schneider has received grant funding from the Canadian Institutes of Health Research, NFL Scientific Advisory Board, IOC Medical and Scientific Research Fund, World Rugby, Mitacs Accelerate, University of Calgary, with funds paid to her institution and not to her personally. She is an Associate Editor of BJSM (unpaid), independent consultant to World Rugby, and has received travel and accommodation support for meetings where she has presented. She led and coordinated the writing of the systematic reviews that informed the 6th International Conference on Concussion in Sport and Amsterdam Consensus Statement, for which she received an educational grant to assist with the administrative costs associated with the writing of the reviews (with funds paid to her institution and not to her personally). She is a member of the AFL Concussion Scientific Committee (unpaid position) and Brain Canada (unpaid position). She works as a physiotherapy consultant and treats athletes of all levels of sport from grassroots to professional. Vicki Anderson financial disclosures include the Australian National Health and Medical Research Council and Medical Research Future fund and research grants; royalties include Pearson Publishing (Test of Everyday Attention); collaboration includes the Australian Football League (Partnership agreement to fund research – funds to her institute) Boards; editorship of the Journal of Neuropsychology, Neuropsychology and Journal of Clinical and Experimental Neuropsychology. Franz E. Babl financial disclosures include the Australian National Health and Medical Research Council and Medical Research Future fund and research grants. 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Giza discloses the following grants and research support: Hit-IQ (2022–2023); NIH NINDS (R01 NS110757 2019–2024); NINDS (U54 NS121688 2021–2026); UCLA Brain Injury Research Center, UCLA Steve Tisch BrainSPORT program, and the Easton Clinic for Brain Health; is a clinical consultant (provides clinical care to athletes) for the NBA, NFL-Neurological Care Program, NHL/NHLPA, and Los Angeles Lakers. He is a member of the Advisory Board (uncompensated) for Major League Soccer, National Basketball Association, and US Soccer Federation. He is a member of the Advisory Board (compensated) for Highmark Interactive; occasionally serves as an expert witness in medicolegal cases; and is a shareholder in Highmark Interactive stock options. He receives book royalties from Blackwell/Wiley Publishing. John J. 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Michael J. McNamee serves as the Chair of the Ethics Expert Group, WADA (2021–23) (paid); is a member of the International Boxing Association, Ethics, and Integrity Committee, (2021–2, resigned Oct 2022) (paid); the Chair for the Therapeutic Use Exemption Fairness Committee (2020–) (paid); and is a member of the Steering Group, Sex Segregation in Sport, IAAF/World Athletics, (2019–20) (unpaid); the International Ice Hockey Federation, Ethics, and Integrity Committee (2019–21) (paid); IOC Consensus Statement Expert Group on Injuries in Children and Adolescents (2017) (unpaid); the Ethics Expert Group, WADA (2016–21) (unpaid); and the IOC Consensus Statement Expert Group on Pain Management (2016) (unpaid). William P. Meehan III WPM receives royalties from ABC- Clio publishing for the sale of the books: *Kids, Sports and Concussion: A Guide For Coaches and Parents*, and *Concussions*; from Springer International for the book *Head and Neck Injuries in*

Young Athlete; and from Wolters Kluwer for working as an author for *UpToDate*. His research is funded, in part, by philanthropic support from the National Hockey League Alumni Association through the Corey C Griffin Pro- Am Tournament and a grant from the National Football League. Laura Purcell is a CASEM Board Member, President 2023–2024; NIH R34 Grant for EPICC Study (Eye Problems In Concussed Children), Site PI; has been a speaker at various conferences; is a CISG member; and an expert panelist for the 6th International Conference on Concussion in Sport (travel and accommodation subsidized). Margot Putukian is a consultant and Chief Medical Officer for Major League Soccer; serves as a senior advisor to the National Football League's Head, Neck, and Spine Committee, is a member of the FA Research Task Force, the NOCSAE Scientific Advisory Committee, and a member of the Concussion in Sport Expert Panel; and also serves on the IOC Mental Health Working Group, the USOPC Mental Health Advisory Committee, the US Soccer Medical Advisory Committee, and has received grant funding from the NCAA-DoD CARE 2.0 project. Rosemarie Scolaro Moser is a director and owner of the Sports Concussion Center of New Jersey, from which she derives income and is President of the Sports Neuropsychology Society from which she does not derive income. Keith Owen Yeates is Editor-in-Chief of the journal *Neuropsychology* and receives an editorial stipend from the American Psychological Association; is an unpaid consulting editor for Archives of Clinical Neuropsychology, Journal of Head Trauma Rehabilitation, and Journal of Neurotrauma; is an unpaid member of the Scientific Advisory Committee for Brain Injury Canada; is the chair of the Canadian Concussion Network, which is funded by a grant from Canadian Institutes of Health Research (CIHR) to the University of Calgary, is a principal investigator (PI) on another grant from CIHR from which he derives no income; is a coinvestigator on research grants from CIHR, the US National Institutes of Health (NIH), Brain Canada Foundation, and National Football League Scientific Advisory Board, but derives income only from the grant from the NIH; receives book royalties from Guilford Press and Cambridge University Press; has received travel support and honoraria for presentations to multiple organizations; has served or serves on the following committees and boards for which he receives honoraria: Independent Data Monitoring Committee (IDMC), Care for Post-Concussive Symptoms Effectiveness (CARE4PCS-2) Trial, National Institute for Child Health and Human Development; Observational Study Monitoring Board (OSMB), Approaches and Decisions in Acute Pediatric TBI (ADAPT) Trial, National Institute of Neurological Disorders and Stroke; National Research Advisory Council, National Pediatric Rehabilitation Resource Center, Center for Pediatric Rehabilitation: Growing Research, Education, and Sharing Science (C-PROGRESS), Virginia Tech University. Roger Zemek has current or past, competitively-funded research grants from Canadian Institutes of Health Research (CIHR), National Institutes of Health (NIH), Health Canada, Ontario Neurotrauma Foundation (ONF), Ontario Ministry of Health, Physician Services Incorporated (PSI) Foundation, CHEO Foundation, University of Ottawa Brain and Mind Research Institute, Ontario Brain Institute (OBI) and Ontario SPOR Support Unit (OSSU) and the National Football League (NFL) Scientific Advisory Board. He holds the Clinical Research Chair in Pediatric Concussion from University of Ottawa and is on the advisory board for Parachute Canada (a non-profit injury prevention charity) and the board of directors for the North American Brain Injury Society (unpaid); and is the cofounder, Scientific Director, and a minority shareholder in 360 Concussion Care, an interdisciplinary concussion clinic. Jon S. Patricios is an Editor of BJSM for which he receives an honorarium; is an unpaid consultant to the World Rugby Concussion Advisory Group, for which he also serves as an Independent Concussion Advisor (fee per consultation); other unpaid positions include being medical advisor to South African Rugby, a member of the Union of European Football Associations (UEFA) Head Injury Advisory Committee, the National Football League (NFL, USA) Head, Neck and Spine Committee, cochair of the Scientific Committee, 6th International Conference on Concussion in Sport (travel and accommodation subsidized), Board member of the CISG, and a Scientific Advisory Board Member of EyeGuide.

COMPANION PAPER: A companion to this article can be found online at www.pediatrics.org/cgi/doi/10.1542/peds.2023-063881.

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