Which symptom assessments and approaches are uniquely appropriate for paediatric concussion?

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ABSTRACT

Objective: To (a) identify post-concussion symptom scales appropriate for children and adolescents in sports; (b) review evidence for reliability and validity; and (c) recommend future directions for scale development.

Design: Quantitative and qualitative literature review of symptom rating scales appropriate for children and adolescents aged 5 to 22 years.

Intervention: Literature identified via search of Medline, Ovid-Medline and Psychnfo databases; review of reference lists in identified articles; querying sports concussion specialists. 29 articles met study inclusion criteria.

Results: 5 symptom scales examined in 11 studies for ages 5–12 years and in 25 studies for ages 13–22. 10 of 11 studies for 5–12-year-olds presented validity evidence for three scales; 7 studies provided reliability evidence for two scales; 7 studies used serial administrations but no reliable change metrics. Two scales included parent-reports and one included a teacher report. 24 of 25 studies for 13–22 year-olds presented validity evidence for five measures; seven studies provided reliability evidence for four measures with 18 studies including serial administrations and two examining Reliable Change.

Conclusions: Psychometric evidence for symptom scales is stronger for adolescents than for younger children. Most scales provide evidence of concurrent validity, discriminating concussed and non-concussed groups. Few report reliability and evidence for validity is narrow. Two measures include parent/teacher reports. Few scales examine reliable change statistics, limiting interpretability of temporal changes. Future studies are needed to fully define symptom scale psychometric properties with the greatest need in younger student-athletes.

The participation of children and adolescents in sports has grown substantially over the past several decades. In the USA alone, some 30 to 45 million children participate annually in non-scholastic sports programmes (National Alliance for Youth Sports, National Council of Youth Sports).1 2 With widespread participation of children as young as 3 or 4 years in athletics, the effects of concussion on the developing brain have come into greater focus. Recently updated annual incidence estimates by the Centers for Disease Control and Prevention3 of “known” sports and recreation related concussions in the US indicate that up to 8.5 million children and adults sustain a concussion. The Second International Concussion in Sport Group meeting in Prague in 20044 recognised the specialised area of concussion management in younger paediatric student-athletes. Concussion to the developing brain of the young student-athlete can be a serious problem that requires early recognition and effective management to reduce serious or catastrophic outcomes.5

To effectively manage concussion in younger student-athletes, they must be understood differently than older, more neurologically mature, athletes.6–9 To do so, it is necessary to use age-appropriate clinical assessment measures and developmentally-appropriate evidence-based management guidelines. In their review of the clinical management of sport-related mild traumatic brain injury in younger children, Kirkwood, Yeates & Wilson10 assert that this age group has not received adequate attention. Younger athletes may be distinguished from older athletes along several dimensions, including biomechanical properties of injury, variations in pathophysiological responses to injury, developmentally-specific neurobehavioural outcomes, and differences in contextual expectations such as learning versus work as a key focus. Systematic tracking of concussed student-athletes’ recovery course is also advocated through serial physical examinations and administration of standardised symptom inventories.

Another critical difference is the central involvement and oversight of the child by the parents versus the independent functioning of adults. While the focus of the concussion evaluation and subsequent management is on the student-athlete, it is standard practice in paediatrics to require active involvement of the parent. The parent is a critical participant in the treatment/recovery process, including return to school, return to sports/recreation and return to everyday social and home activity. The teacher and other school personnel such as coaches also become key partners in the process as well. The student-athlete’s everyday environments at home and at school serve as important venues for observing post-concussion symptoms. Parents and teachers possess a wealth of information about the child’s behaviour and functional status in these settings that is directly relevant to an assessment of their post-concussive symptoms. Therefore, throughout the course of the injury, parents, teachers and other adults are important for obtaining symptom reports. Furthermore, a rich tradition exists in utilising structured behaviour rating systems to assess behavioural and neuropsychological constructs.9–11 Parent/teacher ratings and child self-report measures of child and adolescent psychopathology, and health status are often used to explore the types and extent of behavioural and somatic health problems in children and adolescents.

Buzzini and Guskiewicz12 discuss the signs, symptoms and management of paediatric concussion for
the medical practitioner. They present key aspects of concussion assessment including essential historical features such as developmental, learning and medical disorders, thorough symptom assessment, previous concussions outside the sport arena, use of protective equipment and change in playing style with/without equipment. These authors also discuss return to play criteria and advocate for an individualised approach that synthesises symptom assessment, formal neuropsychological testing and postural-stability testing. Lovell and Fazio further suggest that children with concussions should be managed differently than adolescents and adults while also acknowledging that we know less about how to appropriately manage this younger age group. They highlight evidence from Hovda and colleagues indicating increased vulnerability to additional brain injury during the acute recovery period (7–14 days) as well as the presence of post-concussion hypotension in younger rat brains which sets up greater vulnerability to a second injury. Age is recognised by these authors as playing a role in recovery although the supporting data for this view comes largely from study of adolescent athletes rather than from younger children. Field et al and Moser et al provide empirical support that high school athletes take significantly longer to recover than collegiate athletes. Collins et al report that at least 29% of high school football players take up to four weeks to reach recovery criteria.

Finally, McCrory et al provides the first data-based paper on sport-related concussion in youth. Their empirical work on neurocognitive functioning in normal children demonstrates significant developmental changes in efficiency of reaction time, decision making, working memory and learning between age 8–15 years, with even subtle decrements in attention and information processing adversely affecting school performance and learning. McCrory and colleagues note that differences between children and adults with concussion may necessitate differences in management of the younger student-athlete. Sports concussion management guidelines were formulated largely for adult athletes while anatomical, physiological, environmental and behavioural differences in younger athletes call for modifications in these guidelines for youth. Although neurocognitive sequelae of sports concussion are largely within the same functional domains as in adults (ie, processing speed, memory, attention and executive function), the consequences may be very different, with a particularly negative impact on educational and social development. While the basic components of the clinical assessment of the younger student-athlete may be similar to established procedures with adults (ie, medical exam, assessment of postural stability and neurocognitive functioning), these findings must be understood within a changing developmental context.

In order to effectively treat children and adolescents who sustain a concussion, developmentally and psychometrically appropriate clinical tools must be available to the clinician to assess the full range of symptoms, neurocognitive functions and balance. Can younger children understand and reliably self-identify the full spectrum of somatic, cognitive, emotional and sleep-related symptoms? Do the reports of parents and teachers contribute important information in the concussion assessment of the young student-athlete? In this paper, we explore available measures of post-concussion symptoms for child and adolescent student-athletes. The question is posed—which symptom scales are appropriate for use in the child and adolescent student-athlete? The extant literature guiding specific assessment of post-concussion symptoms in sport-related concussion is explored for the full developmental continuum from youth through college.

**METHODS**

**Data sources**

Several strategies were employed to maximise the number of possible studies for review. Three electronic databases were searched through 15 December 2008 (Medline, Ovid-Medline, PsycInfo) for articles relevant to the use of post-concussion symptom scales with children or adolescents. The first searches were specific to post-concussion symptom scales in youth and/or adolescent sports. Following this narrow search focus, the terms were broadened to include all studies that mention post-concussion symptom assessment in children and/or adolescents. Thus, initial search terms were: (1) post-concussion symptom scale; (2) graded symptom checklist/graded symptom scale; (3) Rivermead post-concussion symptom questionnaire; (4) post-concussion symptom inventory. Search terms were further broadened to include sport applications, additional aspects of post-concussion symptoms and age ranges: (5) Rivermead AND (concussion OR post-concussion syndrome); (6) post concus- AND sport; (7) post-concussion syndrome AND sport; (8) post-concussion syndrome OR brain concussion OR concussion) AND (affective symptoms OR behavioural symptoms OR symptoms) AND Sport; (9) post-concussion syndrome AND sport, and; (10) post-concussion symptom(s) AND sport. Reference lists from retrieved and appropriate articles were reviewed for additional on point article references. Finally, recognised experts in the field were solicited for recommendations of empirically-based literature.

**Study selection**

Inclusion criteria for appropriate studies included published empirical articles and published abstracts (journal or conference proceedings) with study participants between five and 22 years. Exclusion criteria included letters, non-empirical conceptual papers, review articles and dissertations. Thus, guiding search criteria were: specified post-concussion symptom measure (eg, post-concussion symptom scale, Rivermead post concussion symptoms questionnaire); sports; mild traumatic brain injury; and youth. Children, adolescent, college. To be included in the final dataset, each article must have used a specified post-concussion symptom scale with a population between the ages of five and 22 years, and must have reported on some aspect of the scale’s psychometric properties (evidence for reliability, validity) and/or serial use.

**Data extraction**

Studies meeting inclusion criteria were initially separated into three groups: (1) published studies with a primary focus on children aged 12 years and younger; (2) published studies with a primary focus on adolescents, aged 13–22 years and; (3) published abstracts.

**Data synthesis**

All data and analyses are summarised in tables 1–3 by study source, study objective, study design, study population, measures used and results according to the evidence for reliability, validity and serial use.

**RESULTS**

A total of 281 articles were identified and reviewed. Of those, 61 appeared to meet initial study selection criteria. After closer examination and exclusion of duplicate articles, and those that did not meet inclusion criteria, 29 articles were selected for review and are summarised in tables 1 to 3. Twenty-five studies
of the symptoms are endorsed, with severity ranging from 0 to 6 (severe symptom) for four domains including cognitive, somatic, emotional and sleep. Scores include the total symptom severity score (ICC = 0.86) and duration (ICC = 0.84) scales. Test-retest reliability good to excellent for the total symptom severity scale (ICC = 0.88 to 0.93) and moderate to good reliability for the individual symptoms severity (ICC = 0.65 to 0.89) and duration (ICC = 0.56 to 0.96) scales.

Validity: not reported

Serial use: 45 day interval between two ratings. No RCI

Reliability: moderate item-total correlations correlation with the total score for most of the symptoms. Internal consistency was moderate to high (α = 0.82). Inter-rater reliability was appropriate.

Validity: predictive: ACE symptom score predicted parent and patient PCSI reports but was less related to pre-concussion baseline ratings, providing evidence of validity for detecting mild TBI. Construct: four factors identified

Serial use: average 7 days post-injury; multiple follow-up visits; no RCI

Reliability: not reported

Validity: concurrent (clinical group differences): Concussed versus non-concussed found at 1, 4 and 12 weeks post-injury

Serial use: significant decrease in symptoms across 3 visits; no RCI

Reliability: not reported

Validity: construct: three replicable factors identified (cognitive, somatic and emotional symptoms) at baseline and 3-months post-injury. Fourth behavioural symptom dimension identified at baseline, not at 3-months. Moderate parent-child correlations between cognitive and somatic symptoms at baseline; weak/non-significant correlations between emotional and behavioural symptoms. At three months, moderate correlations between cognitive symptoms and weak/non-significant correlations were identified for somatic, emotional and behavioural symptoms

Serial use: two post-injury administrations: 1 week, 3 months. No RCI

Reliability: not reported (previous study showed a 6 month test-retest mean within group correlation 0.55)

Validity: concurrent: group differences in 4 factors (emotional, behavioural, cognitive and somatic) between concussed and orthopaedic groups. Cognitive/somatic symptoms declined over time, while emotional/behavioural symptoms increased. Convergent: emotional/behavioural symptoms were predicted by injury severity, concurrent cognitive functioning soon after the injury and concurrent parent and family burden later in time

Serial use: three administrations, six month intervals. No RCI

Reliability: not reported

Validity: concurrent: group differences for concussion from baseline to 3 months with cognitive and somatic symptoms more so than controls

Serial use: retrospective baseline and 3 months post-injury. No RCI

ACE, acute concussion evaluation; GSS, graded symptom scale; HBI, health and behaviour inventory; PCSI, post-concussion symptom inventory; RCI, reliable change indices; RPCSQ, Rivermead post-concussion symptom questionnaire; TBI, traumatic brain injury.

Table 1 Psychometric evidence of concussion symptom measures in the student-athlete age 5–12, published studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Study objective</th>
<th>Study design</th>
<th>Study sample</th>
<th>Symptom measure</th>
<th>Psychometric evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maier (2008)</td>
<td>Test-retest reliability of self-report symptom measures</td>
<td>Within-subjects, repeated measures</td>
<td>126 non-concussed middle school students (mean age = 13.1 yr)</td>
<td>GSS; 16 items</td>
<td>Reliability: moderate internal consistency for symptom severity (0.88) and duration (0.84) scales. Test-retest reliability good to excellent for the total symptom severity scale (ICC = 0.88 to 0.93) and moderate to good reliability for the individual symptoms severity (ICC = 0.65 to 0.89) and duration (ICC = 0.56 to 0.96) scales. Validity: not reported Serial use: 45 day interval between two ratings. No RCI</td>
</tr>
<tr>
<td>Gioia (2008)</td>
<td>Demonstrate psychometric properties of the ACE</td>
<td>Retrospective, repeated measures</td>
<td>354 parents of children ages 3–18 with concussion</td>
<td>ACE; 26 items (yes/no response)</td>
<td>Reliability: moderate item-total correlations correlation with the total score for most of the symptoms. Internal consistency was moderate to high (α = 0.82). Inter-rater reliability was appropriate. Validity: predictive: ACE symptom score predicted parent and patient PCSI reports but was less related to pre-concussion baseline ratings, providing evidence of validity for detecting mild TBI. Construct: four factors identified Serial use: average 7 days post-injury; multiple follow-up visits; no RCI</td>
</tr>
<tr>
<td>Gagnon (2005)</td>
<td>Evaluate children’s self-efficacy relation to the practice of physical activities prior to and after concussion</td>
<td>Case control</td>
<td>34 children with concussion ages 8–16</td>
<td>RPCSQ; 16 items</td>
<td>Reliability: not reported Validity: concurrent (clinical group differences): Concussed versus non-concussed found at 1, 4 and 12 weeks post-injury Serial use: significant decrease in symptoms across 3 visits; no RCI</td>
</tr>
<tr>
<td>Ayr (2009)</td>
<td>Investigate long-term dimensions of post-concussive symptoms</td>
<td>Prospective longitudinal cohort</td>
<td>186 children with concussion ages 8–15 (mean age = 11.96 yr) and their parents</td>
<td>HBI—parent and child report forms; 50 items</td>
<td>Reliability: not reported Validity: construct: three replicable factors identified (cognitive, somatic and emotional symptoms) at baseline and 3-months post-injury. Fourth behavioural symptom dimension identified at baseline, not at 3-months. Moderate parent-child correlations between cognitive and somatic symptoms at baseline; weak/non-significant correlations between emotional and behavioural symptoms. At three months, moderate correlations between cognitive symptoms and weak/non-significant correlations were identified for somatic, emotional and behavioural symptoms Serial use: two post-injury administrations: 1 week, 3 months. No RCI</td>
</tr>
<tr>
<td>Yeates (2001)</td>
<td>Examine the prevalence and correlates of neurobehavioral symptoms during the first year following concussion</td>
<td>Prospective longitudinal cohort</td>
<td>122 parents of children ages 6–12 years with either concussion or orthopaedic injuries</td>
<td>Post-injury symptom checklist—parent report; 30 items (15 considered)</td>
<td>Reliability: not reported (previous study showed a 6 month test-retest mean within group correlation 0.55) Validity: concurrent: group differences in 4 factors (emotional, behavioural, cognitive and somatic) between concussed and orthopaedic groups. Cognitive/somatic symptoms declined over time, while emotional/behavioural symptoms increased. Convergent: emotional/behavioural symptoms were predicted by injury severity, concurrent cognitive functioning soon after the injury and concurrent parent and family burden later in time Serial use: three administrations, six month intervals. No RCI</td>
</tr>
<tr>
<td>Yeates (1999)</td>
<td>Examine the incidence and neuropsychological, behavioural and neuroimaging correlates of post-concussive symptoms</td>
<td>Prospective longitudinal cohort</td>
<td>34 children with concussion ages 8–15 years and their uninjured sibling</td>
<td>HBI; 62 items</td>
<td>Reliability: not reported Validity: concurrent: group differences for concussion from baseline to 3 months with cognitive and somatic symptoms more so than controls Serial use: retrospective baseline and 3 months post-injury. No RCI</td>
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</table>

Included athletes ages 13–22; 11 studies included younger children age 5–12 years, with four focused exclusively on this younger group. Four scales were found in clinical use: post-concussion symptom scale (PCS), graded symptom checklist/scale (GSC/GSS), Rivermead post concussion symptom questionnaire (RPCSQ) and post-concussion symptom inventory (PCSI/ACE). In addition, a fifth research-based symptom scale was identified: health and behaviour inventory (HBI). Descriptions of the symptom scales are as follows:

Graded symptom checklist/scale
The graded symptom checklist/scale (GSC/GSS) are self-report measure of concussive symptoms which are derivatives of the head injury scale self-report concussion-symptoms scale (HIS). The GSS is a 16-item version where both severity and duration of the symptoms are endorsed, with severity ranging from 0 to 6 (not having the symptom) to 6 (severe symptom) and duration, 0–7, for the number of days during the week that symptoms were present. The GSC is a 17–20 item measure with symptoms rated on a 7-point Likert scale ranging from 0 (no symptom) to 6 (severe symptom), for four domains including cognitive, somatic, emotional and sleep. Scores include the total number of symptoms, total severity of symptoms and severity of each individual symptom.

Acute concussion evaluation
The acute concussion evaluation (ACE) is a 26-item symptom measure for parents/informants or patient self-report with a yes/no response format for use by athletic trainers, clinicians, physicians or others to assess individuals with known or suspected concussions. The ACE also contains appropriate
background questions and questions about injury characteristics.

**Rivermead post-concussion symptom questionnaire**

The RPCSQ is a 16-item self-report graded rating scale of the severity of concussion-related symptoms. For each item, scores range from 0 (absent) to 4 (severe problems) over the past 24 hours relative to pre-morbid levels.

**Health and behavioural inventory**

The health and behavioural inventory (HBI) contains a variety of somatic, affective, cognitive and behavioural symptoms, originally developed to assess sequelae of all severity levels of TBI. The HBI has been revised from a 62-item measure to a 50-item measure. Parent informant and child self-report forms are available for ages 8–15 years, with changes in wording from the Br J Sports Med 2009;43(Suppl I):i13–i22. doi:10.1136/bjsm.2009.058255

**Post-concussion symptom inventory**

The post-concussion symptom inventory (PCSI) is a set of symptom scales for parents and teachers (26-item, 7-point Likert scale) and developmentally-specific self-report forms for children ages 5 to 7 (13 items, 5-point Likert), ages 8–12 (25-item, 3-point Likert scale) and 13–18-year-olds (26-item, 7-point Likert scale). Symptoms reflect physical, cognitive, emotional and sleep domains.

**Post-concussion scale**

The post-concussion scale (PCS) is a 22-item self-report of the severity of concussion-related symptoms on a 7-point Likert scale, from 0 (no symptom) to 6 (severe symptom). The PCS can be administered via computer as part of the immediate post-concussion assessment and cognitive testing (ImpACT), computerised neurocognitive test battery or by paper.

The psychometric findings for the 29 studies are summarised in tables 4 and 5 for the two age groups (5–12, 13–22, respectively). These tables indicate the number of studies meeting the above inclusion criteria by measure, the number of lines of evidence for reliability and validity, and the number of studies that calculated or applied reliable change indices (RCI).

Each study was examined for the breadth of the reliability and validity analyses. For reliability, this was defined as the number of lines of evidence for reliability that were conducted (eg, coefficient alpha, test-retest, inter-rater, split-half reliability). For validity, this was defined as the number of lines of evidence for validity (eg, internal structure (factor analysis), relationships to other variables (convergent/discriminant) and criterion (concurrent—distinguishing between groups, examining change over time; and
<table>
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<tr>
<th>Study</th>
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</tr>
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<tbody>
<tr>
<td>McCaffrey (2007)²⁴</td>
<td>Determine the relation between force caused by head impact and subsequent neurocognitive or balance symptoms</td>
<td>Double-blind, repeated measures</td>
<td>43 non-concussed college athletes (age mean = 20.7, SD = 1.62); Sport: football</td>
<td>GSC; 18 items</td>
<td>Reliability: not reported; Validity: increase in number of symptoms (but not severity) following 90 g force taken but not “low impact” (&lt;60 g force); 2 symptoms on average. Minimal change in symptoms following &gt;90 g of force was not corroborated by change in balance or cognition</td>
</tr>
<tr>
<td>Register-Mihalik (2007)²⁵</td>
<td>Examine the effects of pre-season baseline headaches and post-traumatic headaches on neurocognitive performance</td>
<td>Retrospective repeated measures study</td>
<td>247 concussed high school and college athletes (age mean = 16.65, SD = 1.87); Sport: mixed</td>
<td>GSC; 20 items</td>
<td>Reliability: not reported; Validity: presence and severity of symptoms correlated with baseline headaches and post-traumatic headaches</td>
</tr>
<tr>
<td>Piland (2006)²⁶</td>
<td>Evaluate the factorial validity of a self-reported measure of concussion symptom severity</td>
<td>Cross sectional study of normative cases</td>
<td>1089 high school athletes (mean age = 16.3, SD = 0.9); Sport: football</td>
<td>GSC; 20 items</td>
<td>Reliability: not reported; Validity: analysis showed 3-factor (eg, somatic, neurobehavioural and cognitive) fit for the 16 items; better 3 factor fit for a model comprised of 9 items. Single second-order factor deemed “concussion symptomatology” found</td>
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<tr>
<td>McCrea (2003)²⁷</td>
<td>Prospectively measure immediate effects and natural recovery course relating to symptoms, cognitive functioning and postural stability following sport-related concussion</td>
<td>Prospective cohort with matched case controls.</td>
<td>1631 college football players (94 injured and 56 controls). Concussion mean age = 20, SD = 1.36, control mean age = 19.20, SD = 1.45; Sport: football</td>
<td>GSC; 17 items</td>
<td>Reliability: not reported; Validity: group differences between concussed and non-concussed controls (through 5 days post injury); average symptom resolution 7 days. Symptom recovery curves similar to recovery curves on balance and neurocognitive function</td>
</tr>
<tr>
<td>McCrea (2005)²⁸</td>
<td>Use standard regression-based methods, with baseline and serial testing paradigm to measure individual rates of cognitive-functional impairment following concussion</td>
<td>Prospective study with matched case controls.</td>
<td>150 college athletes (94 injured and 56 controls) Concussion mean age = 20.04, SD = 1.36; control mean age = 19.20, SD = 1.45; Sport: football</td>
<td>GSC; 17 items</td>
<td>Reliability: not reported; Validity: sensitivity and specificity were reported on the GSC immediately following injury (0.89 and 1.00, respectively). Specificity remained at 1.00 through day 7 post-injury; sensitivity declined successively. Symptom recovery generally preceded recovery on balance and cognitive testing</td>
</tr>
<tr>
<td>Guskiewicz (2003)²⁹</td>
<td>Estimate the incidence of concussion and time to recovery after concussion</td>
<td>Prospective longitudinal cohort study;</td>
<td>2905 college athletes (184 injured); Sport: football</td>
<td>GSC; 17 items</td>
<td>Reliability: not reported; Validity: GSC used serially post-injury, demonstrated linear recovery</td>
</tr>
<tr>
<td>Iverson &amp; Goetz. (2004)³⁰</td>
<td>Describe practical considerations for interpreting change following brain injury</td>
<td>Book chapter analyzing prospective cohort</td>
<td>200 collegiate football players</td>
<td>PCS; 22 items</td>
<td>Reliability: not reported; Validity: interpretation of post- concussion symptom scores must be based on baseline rates</td>
</tr>
<tr>
<td>Lovell (2006)³¹</td>
<td>Present psychometric and clinical properties of the PCS</td>
<td>Cross-sectional study with normative and clinical samples</td>
<td>1746 high school (n = 707) and college (n = 1039) athletes (260 injured)</td>
<td>PCS; 22 items</td>
<td>Reliability: high internal consistency (Cronbach α = .87) and moderate reliability (test-retest = .55) at beginning and end of season</td>
</tr>
<tr>
<td>McClnchey (2006)³²</td>
<td>Serially assess cognitive and symptom-report of concussed athletes</td>
<td>Prospective cohort</td>
<td>104 concussed high school and college athletes (age mean = 16.11, SD = 2.22); Sport: unspecified</td>
<td>PCS; 22 items</td>
<td>Reliability: not reported; Validity: discriminated between baseline and post-injury on visits 1 and 2 but not 3 (day 14 on average). Symptom report and recovery pattern similar to neurocognitive performance</td>
</tr>
<tr>
<td>Collins (1999)³³</td>
<td>Prospectively assess premorbid variables with neuropsychological performance and to evaluate post-concussion recovery</td>
<td>Prospective cohort with normative and clinical samples</td>
<td>393 non-concussed collegiate athletes (age age mean = 20.4, SD = 1.7), with concussed sample of 16</td>
<td>PCS; 20 items</td>
<td>Reliability: not reported; Validity: increase in symptom report related to number of previous concussions</td>
</tr>
<tr>
<td>Collins (2003)³⁴</td>
<td>Examine relationship between on-field markers of concussion severity and post-injury neuropsychological and symptom presentation</td>
<td>Case control</td>
<td>78 concussed high school and college athletes (ages = 14–22); Sport: mixed (football n = 64)</td>
<td>PCS; 22 items</td>
<td>Reliability: not reported; Validity: symptom scores similar to good versus poor outcome classification based on neuropsychological performance</td>
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predictive—accuracy of the measure predicting criterion score at later time). A single study can provide multiple lines of evidence, adding to the strength of its psychometric properties.

**Age 12 and younger**

**Quantity of evidence**

Ten studies were identified that investigated four different symptom scales with children 12 years and younger as follows: GSC/GSS (1), RPCSQ (1), PCSI/ACE (5), HBI (3). The PCSI/ACE and HBI included parent symptom reports in addition to child reports whereas the PCSI included a study of teacher symptom reports. Evidence for validity was presented in nine of the 10 studies covering three measures, whereas evidence for reliability was provided in only six of the 10 studies for two measures. While six of the 10 studies included serial administrations over time, none examined Reliable Change Index (RCI) metrics explicitly.

**Psychometric evidence**

**GSC/GSS (child scale only)**

One study with two lines of evidence for reliability (internal consistency, test-retest). No lines of evidence for validity are presented. No serial use or examination of reliable change. Age range restricted to older children (middle school) although not fully specified.

**RPCSQ (child scale only)**

One study with two lines of evidence for reliability are presented. Two lines of evidence for validity are presented (discriminating concussed from non-concussed groups, demonstrating sensitivity
Summary of psychometric evidence, age 5–12

<table>
<thead>
<tr>
<th>Measure</th>
<th>Studies using measure</th>
<th>Lines of evidence for reliability</th>
<th>Lines of evidence for validity</th>
<th>Serial use RCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSC/GSS</td>
<td>7</td>
<td>1</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>RPCSQ</td>
<td>10</td>
<td>4</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>PCSI (child)</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>PCSI (adolescent)</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>PCSI/ACE (parent)</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>PCSI/ACE (teacher)</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>HBI (parent, child)</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

ACE, acute concussion evaluation; GSC/GSS, graded symptom checklist/scale; HBI, health and behavioural inventory; PCSI, post-concussion symptom inventory; RPCSQ, Rivermead post-concussion symptom questionnaire.

Summary of psychometric evidence, age 13–22

<table>
<thead>
<tr>
<th>Measure</th>
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<td>GSC/GSS</td>
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</tr>
<tr>
<td>RPCSQ</td>
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<td>4</td>
<td>13</td>
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<tr>
<td>PCSI (child)</td>
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<td>0</td>
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<tr>
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<td>0</td>
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<td>PCSI/ACE (teacher)</td>
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<td>0</td>
</tr>
<tr>
<td>HBI (parent, child)</td>
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<td>4</td>
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</table>

ACE, acute concussion evaluation; GSC/GSS, graded symptom checklist/scale; HBI, health and behavioural inventory; PCSI, post-concussion symptom inventory; RPCSQ, Rivermead post-concussion symptom questionnaire.

To change over time. Serial use was indicated but no examination of reliable change metrics. Age range 8–15 years.

**PCSI (child, parent, teacher scales)**

Child: six studies. Four lines of evidence for reliability are presented (internal consistency, test-retest, inter-rater reliability) across four studies. All six studies provided 12 lines of evidence for validity including internal structure (factor analysis), discriminating group differences (concussed versus non-concussed, age-related differences), changes over time and relationships to other measures (convergent/discriminant). Serial use was indicated in one study but no examination of reliable change metrics. Age range 5–12 years.

Parent scale: four studies. Three lines of evidence for reliability presented (internal consistency, test-retest, inter-rater) across two studies. All four studies provided ten lines of evidence for validity including internal structure (factor analysis), discriminating group differences, changes over time and relationships to other measures (convergent/discriminant). Serial use was indicated in one study but no examination of reliable change metrics. Age range 5–12 years.

Teacher scale: one study. No evidence for reliability presented. Two lines of evidence for validity reported in this study including: examination of symptom base rates and concurrent validity. No serial use or RCI analyses conducted. Age range 5–18 years.

**HBI (parent and child scales)**

Child/parent scales: three studies. No lines of evidence for reliability reported. Seven lines of evidence for validity reported in the three studies including: internal structure (factor analysis), relationships to other measures (family burden) and criterion (discriminating group differences, changes over time) to change over time. Serial use was indicated but no examination of reliable change metrics. Age range 8–15 years.

**Age 13–22**

**Quantity of evidence**

In the older age group, age 13–22, 25 studies were identified, investigating five different symptom scales as follows: GSC/GSS (7), PCS (10), RPCSQ (3), PCSI/ACE (3), HBI (2). Overall, evidence for validity was presented in most studies (24 studies, five measures) whereas evidence for reliability was provided in fewer studies (seven studies, four measures). Whereas 18 of the 25 studies included serial administrations, only two examined reliable change index metrics explicitly.

**Psychometric evidence**

**GSC/GSS (self-report)**

Seven total studies. Two lines of evidence for reliability. Six of seven studies examined evidence for validity providing nine lines of evidence including: relationships to other variables (convergent), internal structure (factor analysis) and criterion (discriminating group differences, sensitive to changes over time). Serial use indicated in four studies with no examination of reliable change.

**PCS (self-report)**

Ten studies. Four lines of evidence for reliability presented (internal consistency, test-retest) across three studies. All ten studies provided 15 lines of evidence for validity including internal structure (factor analysis), discriminating group differences, changes over time and relationships to other measures (convergent/discriminant). Serial use was indicated in seven studies with examination of reliable change metrics in one study.

**RPCSQ (self-report)**

Three studies. Three lines of evidence for reliability (internal consistency, test-retest, split-half) were presented. Four lines of evidence for validity were presented (discriminating concussed from non-concussed groups, demonstrating sensitivity to change over time). Serial use was indicated but no examination of reliable change metrics.

**PCSI (self-report adolescent, parent, teacher scales)**

Self-report: two studies. No lines of evidence for reliability were presented. The two studies provided four lines of evidence for validity including analyses of symptom base rates, criterion (concordance with other raters), discriminating group differences. Serial use was not conducted; no examination of reliable change metrics. Age range 13–18 years.

Parent scale: three studies. Two lines of evidence for reliability presented (internal consistency, test-retest) across one study. All three studies provided seven lines of evidence for validity including internal structure (factor analysis), criterion (concordance with other raters), discriminating group differences, changes over time and analysis of symptom base rates. Serial use was indicated in one study but no examination of reliable change metrics. Age range 5–18 years.

Teacher scale: one study. No evidence for reliability presented. Two lines of evidence for validity reported in this study including: examination of symptom base rates and concurrent validity. No serial use or RCI analyses conducted. Age range 5–18 years.
HBI (parent and child scales)
Self-report/parent scales: two studies. No lines of evidence for reliability reported. Four lines of evidence for validity reported in the two studies including: internal structure (factor analysis) and criterion (discriminating group differences, changes over time) validity. Serial administration not conducted and no RCI analyses. Age range: 8–15 years.

DISCUSSION
Clinical measures for post-concussion symptom assessment in student-athletes across the age span from 5 to 22 years were reviewed for their psychometric qualities and appropriateness for clinical use. A literature search produced 11 suitable studies for children aged 5–12 years and 22 for adolescents and young adults aged 13–22 years. Data for the younger 5–12 year age group was sparse with only three studies of clinical measures in the published literature, three studies of research measures and five studies in published abstract form. There is no published data currently examining symptom assessment in children under the age of eight, although several published abstracts examine this issue. The bulk of the literature on symptom assessment exists for adolescent (high school) and young adult (college) ages. Four measures were identified that are currently in active clinical use, including the GSC (scale), PCS, RPCSQ, PCSI/ACE. A fifth paediatric symptom measure, the HBI, was identified although its current use is limited to the research context. The HBI was included in the review as it is instructive from a psychometric point of view in the 5–12 year age range and it employs both self-report and parent-report measures.

Reasonable psychometric evidence exists for each of these measures to guide their clinical use. It is important to recognise, however, that the available evidence is somewhat imbalanced. The majority of studies provide evidence for validity but less for reliability. With respect to the validity studies, the focus is somewhat narrow with an emphasis largely on the symptom scales’ discrimination between concussed and non-concussed groups. While all five symptom scales demonstrate evidence for validity based on concurrent criterion (conclusion) that lends significant weight to the clinical utility of the scale, it is only one of several lines of evidence for the validity of a measure.

Validity is a unitary concept that is based on the accumulation of multiple lines of evidence, depending on the purpose of the measure. Other types of evidence appropriate for post-concussion symptom scales include consistency of internal structure usually demonstrated via factor analyses, convergence with other measures of the same or similar constructs demonstrated by correlations between measures and discrimination of scores with other measures of different constructs (eg, anxiety, depression, oppositional behaviour) demonstrated by limited correlations between measures. As noted, the reviewed studies focus on concurrent evidence (ie, discriminating between concussed and non-concussed groups) but few report evidence for validity based on the internal structure of the measure or convergence with other measures. Evidence for validity based on the internal structure is quite important also as concussion symptomatology generally is not viewed as a unitary construct but instead composed of symptom subgroups such as somatic, cognitive, emotional and sleep domains. In the current review, three measures report the factor structure, the self-report PCS with adolescents, the PCSI for child and parent reports, and the HBI for child and parent reports.

Understanding the convergence of the symptom scales with other measures is also important because of the overlap of concussion symptomatology with other medical, emotional and behavioural disorders, and the likely prevalence of premorbid attentional, learning or psychiatric disorders. Few studies examined these relationships although studies with the HBI did so with family burden and social-emotional measures. Studies with the GSC and PCS examined relationships with neuropsychological test variables. In a related vein, some of the extant studies appropriately controlled for pre-existing psychiatric or behavioural conditions such as attentional and learning disabilities in order to demonstrate the reliability and validity of the measures in normative samples. It is important, however, to understand how such conditions might affect ratings on these measures. Given the high base rates of attention and learning disabilities in school-aged children and adolescents, it is important to understand how the behavioural characteristics of such children affect post-concussion symptom reporting.

While the majority of studies reviewed included evidence for validity of the study measure, few reported evidence of reliability. Only two of the five measures applicable to younger children (GSS, PCSI) presented reliability data in contrast to four of five measures presenting evidence of validity. Amongst the measures for adolescents and college students, reliability data was reported for only three of the five measures (PCS, RPCSQ, PCSI) in contrast to validity data for all five. It may be that the reliability of a symptom measure is viewed as less clinically relevant than evidence of validity (such as sensitivity to clinical vs control groups). To the contrary, it is important to establish reliability for any behavioural measure for a number of reasons. Reliability is an essential component of validity, and sets the upper bound of possible validity. It is essential to know the degree to which a measure is internally consistent (ie, do the items measure the same construct, such as post-concussion symptoms) and stable over time (ie, are scores on the measures likely to vary due to error). Reliability is also a critical component for the metrics that underlie the determination of real change on a symptom measure—such as the reliable change index (RCI). Metrics like the RCI are important statistics that describe the measure’s sensitivity to true change in symptoms versus change in scores that may be attributable to error variance. Symptom assessments in sport-related concussions are typically conducted serially to monitor the athlete’s recovery. Therefore, knowing the scale’s reliability contributes to understanding the degree to which the scale can reliably detect change in reported symptoms.” Interestingly, in our review, the majority of measures reported serial administrations but did not calculate or apply reliable change indices. Only two measures examined this metric explicitly, the PCS and the RPCSQ.

Examination of inter-rater agreement, another form of reliability, is reported for the two measures (HBI, PCSI) that gather symptom ratings from the child and parent. These studies explore whether multiple reporters enhance diagnostic sensitivity, a particularly important issue in the reliable assessment of post-concussion symptoms in children.

Understanding the typical degree of agreement between child or adolescent reports and their parents’ or teachers’ ratings is important information necessary to facilitate integration of the data.

Few studies examined the age-specificity of the scales, a particularly relevant line of evidence for validity for a paediatric symptom scale. The PCSI examined the developmental appropriateness of wording and response options for children age 5–12 years. The scale for the 5–7-year-old children was significantly shortened (15 items) and simplified (3-point rating). In addition, age-specific symptom base rates and specific symptom...
predictors of outcome were explored with this scale with unique findings based on age.

This review highlights the fact that evidence-based sport-related symptom assessment in preadolescents lags behind that of the adolescent and young adult. The limited extant literature makes one theme loud and clear: younger student-athletes need to be managed differently than adults and adolescents. There are marked differences in development and life circumstances between young children and adolescents or adults that may render them more susceptible to injury, that place them at greater cognitive developmental risk, and that impact them outside the sports arena (eg, school). These differences call for a broader model of assessment and management. The sports concussion assessment in the younger student-athlete must consider more than return to play decisions but also including appropriate guidance in return to school and home life. It follows, then, that post-concussion evaluation and intervention must be necessarily broad to encompass these key differences and needs. Symptom assessment data from not only the child but also from parents and teachers can provide a more reliable and valid assessment picture, enabling intervention for the young student-athlete’s symptom manifestation and functional status in their key environments at home and school. An explicit paediatric model of concussion assessment advocates for the child’s active inclusion in the post-concussion evaluation but also actively incorporates parents and teacher, while appreciating both the limits and advantages of the child’s self-report. The field of concussion evaluation and management in younger children is early in development and must continue to generate evidence to support effective assessment and management measures for the paediatric sport concussion clinician.

FUTURE RESEARCH

This review points to the need for several areas of future research. A clear need exists to develop age-specific measures, particularly for children age 5–12 years. The symptom vocabulary and ability of children to self-identify symptoms across this eight year range varies widely, necessitating clinical measures sensitive to these differences. Future studies should also incorporate standardised symptom ratings from other observers in addition to self report measures. Active involvement of the parent in the evaluation of their child’s health status is common. It is important to examine, however, how child, parent and/or teacher may be integrated to enhance sensitivity of the measures. The reliability of symptom report in younger pre-adolescent children may be less certain than for older reporters due to a variety of factors, including a concrete cognitive style, limited sense of time, lack of familiarity with symptom terminology, difficulty judging “grades” or severity of symptoms and social-emotional maturity. Important to this process is what parent and teacher observations add to the child’s self report rather than whether or not parent observations are a good substitute for child reports. Parsons et al noted that the question should not be “who is right,” but “what does each rater contribute to our understanding of paediatric health related quality of life?”

Finally, more comprehensive investigation of the psychometric properties of symptom scales is necessary, including the examination of multiple lines of evidence for reliability and validity. A specific focus on evidence for reliability should be emphasised with specific relevance and application to reliable change metrics in symptom monitoring. Greater specification of the internal structure of the symptom scales is also warranted, as illustrated with the HBI, as different symptom domains (eg, somatic, cognitive) may be associated with variations in recovery. With a strong psychometric basis for symptom assessments, clinicians can have greater confidence in their use of these tools for evaluating and managing the child with a concussion.

Competing interests: Dr Gioia is a co-author of the ACE and PCSI. No authors have competing financial interests.

Funding: This paper was supported in part by grants from the CDC # U17/CCU323352-01, NIH # 5-M01-RR-020359-02, and NIH # P30/HD046777-07.

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G A Gioia, J C Schneider, C G Vaughan, et al.

doi: 10.1136/bjsm.2009.058255

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