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Psychometric Characteristics of the Postconcussion Symptom Inventory in Children and Adolescents

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Abstract

Psychometric characteristics of the Postconcussion Symptom Inventory (PCSI) were examined in both concussed ($n = 633$) and uninjured ($n = 1{,}273$) 5 to 18 year olds. Parent- and self-report forms were created with developmentally appropriate wording and content. Factor analyses identified physical, cognitive, emotional, and sleep factors; that did not load strongly or discriminate between groups were eliminated. Internal consistency was strong for the total scales ($\alpha = 0.8$–0.9). Test–retest reliability for the self-report forms was moderate to strong (intraclass coefficients, $ICCs = 0.65$–0.89). Parent and self-report concordance was moderate ($r = .44$–$.65$), underscoring the importance of both perspectives. Convergent validity with another symptom measure was good ($r = .8$). Classification analyses indicated greater discriminability from parent report, but caveats to this are presented. With strong psychometric characteristics, the four versions of the PCSI capture important post-concussion symptoms and can be utilized to track recovery from pediatric concussion and guide treatment recommendations.

Keywords: Traumatic brain injury; Brain concussion; Symptom checklists

Mild traumatic brain injury (mTBI), more commonly called concussion, is defined as an injury resulting from a direct or indirect force to the head causing neurological impairment (e.g., amnesia, loss of consciousness, confusion) typically followed by a range of signs and symptoms, balance impairment, and cognitive effects that resolve over time (McCrory et al., 2009). Concussions result in >100,000 Emergency Department visits for children and adolescents each year (Bakhos, Lockhart, Myers, & Linakis, 2010). Increased recognition has subsequently resulted in increased diagnostic rates in children and adolescents over the past decade (Lincoln et al., 2011).

Standardized assessment of symptoms following a concussion is of paramount importance across recovery, as guidelines have long emphasized the importance of being asymptomatic prior to resuming high-risk activities (McCrory et al., 2005). Postconcussion symptoms are often concomitant with impairments in specific neurocognitive abilities (Broglio, Sosnoff, & Ferrara, 2009), each being important to assess (Broglio, Macciocchi, & Ferrara, 2007; Covassin, Elbin, & Nakayama, 2010; Fazio, Lovell, Pardini, & Collins, 2007). Concussion signs and symptoms can be relatively non-specific (i.e., reported in many individuals who have not sustained a concussion), though their manifestation can be more frequent and severe following a concussion (Mittenberg, Wittner, & Miller, 1997; Taylor et al., 2010; Yeates et al., 2001). Pediatric rating scales should not simply contain identical content and wording as adult measures because of important cognitive differences across the developmental spectrum. Currently, developmentally and psychometrically appropriate symptom assessment tools for children have lagged behind that of adults (Gioia, Schneider, Vaughan, & Isquith, 2009a; Janusz, Sady, & Gioia, 2012), with only a few presented in the literature (Ayr, Yeates, Taylor, & Browne, 2009; Randolph et al., 2009). To assist the clinical evaluation of the child following a concussion, standardized assessment of symptoms with measures demonstrating appropriate psychometric properties is essential.

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Characteristics of Symptom Assessment Tools

Good symptom assessment tools have several important characteristics including multiple informants, developmentally appropriate wording and item content, correct groupings of symptoms, and appropriate reliability and validity for specific purposes (Gioia et al., 2009a). When assessing children, input from multiple sources is preferred (Achenbach, McConaughy, & Howell, 1987), particularly from parents, as both parents and children can provide unique perspectives. When crafting the wording of symptom items (McCrory et al., 2009), consideration must be given to the child's less well-developed, more concrete vocabulary, limited sense of time (e.g., discriminating events from yesterday compared with events from last week), and greater difficulty discerning different levels of symptom severity (Varni, Limbers, & Burwinkle, 2007; Wallander, Schmitt, & Koot, 2001).

Symptom subgroups can be useful clinically to understand how an injury manifests for any individual, and symptom clusters may have distinct recovery trajectories (Taylor et al., 2001) or implications for management. Adult symptom measures commonly report cognitive, somatic, and emotional subgroups (Axelrod et al., 1996; Bohnen, Wijnen, Twijnstra, van Zutphen, & Jolles, 1995; Cicerone & Kalmar, 1995; Piland, Motl, Guskiewicz, McCrea, & Ferrara, 2006) and in children and adolescents, there is also evidence for sleep-related symptoms (Ayr et al., 2009; Gioia, Collins, & Isquith, 2008; Piland, Motl, Ferrara, & Peterson, 2003).

Symptom questionnaires should be reliable and valid for their intended uses (Gioia et al., 2009a). Several types of reliability should be assessed: internal consistency of symptoms within each factor, interrater agreement across symptom types, and test–retest reliability over time. There is a dearth of research currently available on the psychometrics of pediatric concussion symptoms scales (see Janusz et al., 2012, for a review of existing scales).

Current Study

The current paper examines the psychometric evidence for the Postconcussion Symptom Inventory (PCSI). The PCSI was adapted from the Postconcussion Scale (Lovell & Collins, 1998; Lovell et al., 2006), initially developed for adult athletes. The original form was modified, based on the consensus of experienced pediatric clinicians, to create separate self-report forms for ages 5–7 (PCSI-SR5; 13 items), 8–12 (PCSI-SR8; 25 items), and 13–18 (PCSI-SR13; 26 items), and a parent-report form for ages 5–18 (PCSI-P; 26 items). Each form was created with consideration for developmental differences in item vocabulary and response options, such that the items for 5–12 year olds contained simplified wording and synonyms (e.g., tired instead of fatigue), a simplified response scale, and fewer items relating to sleep monitoring on the PCSI-SR5. The four versions of the PCSI were examined for item content, factor structure, and reliability (internal consistency, rater concordance, and test–retest), with the prediction that there would be a scaling back of items based on low endorsement rates or absence of difference between injured and uninjured samples. The four forms of the PCSI were examined for their utility to assist diagnostic classification via discriminant function analyses on the self-report and parent-report separately and in combination, by age group. Classification statistics (Chelune, 2010) were then applied to inform users about the sensitivity and specificity of the PCSI in addition to its utility in clinical decision-making (i.e., likelihood ratios, predictive values, odds ratios, classification accuracy).

We expected to find support for multiple factors, based on previous research, and that internal consistency would be higher for ratings for individuals with concussion compared with no injury. We expected moderate levels of rater concordance, reflecting differing perspectives in children and their parents, and strong evidence for test–retest reliability of ratings in uninjured individuals. We expected that classification rates would be strongest for the use of the parent and self-report PCSI in combination at all ages.

Method

Participants

Participants included children and adolescents with concussion ($n = 663$) and without ($n = 1{,}375$), 5–18 years of age. Participants with concussion were seen for outpatient clinical evaluation at a large regional hospital, with inclusion criteria being a diagnosed concussion sustained within 30 days of the evaluation, and clinician determination that the individual was not yet recovered (based on a combination of symptoms, neurocognitive testing, and other clinical features). The 30-day cutoff was chosen to maximize sample size while still capturing those with active concussion. Of note, there were no differences in mean symptom rating between those seen <7 days postinjury compared with 14–30 days. Participants without concussion were a mixture of individuals recruited from local schools and athletic teams as well as individuals who elected to undergo baseline (preinjury) assessment (no significant differences on demographic variables or ratings between these groups), and we excluded any with a reported history of diagnosed ADHD, learning disability, or neurologic disorder (e.g., seizures, brain tumor, moderate–severe TBI). Uninjured participants were also excluded if they reported concussion within the previous year. Data were collected under IRB approval, with informed consent obtained from parents and assent from children and adolescents.

Most participants (71% of injured and 80% of uninjured) comprised parent–child pairs; the remainder were parent only (18% of injured, 19% of uninjured) or child only (5% of injured, 2% of uninjured). Demographic information is presented in Table 1, and injury characteristics for the injured sample are presented in Table 2.

Measures

The four versions of the PCSI were the measures of interest. Preliminary psychometric characteristics (i.e., internal consistency of the original total scales, prior to factor analysis) were presented in a previous publication using a different sample (Gioia, Schneider, Vaughan, & Isquith, 2009a). For each sign or symptom, the rater was instructed to report the degree of symptom expression or experience over the time frame "yesterday or today." The inventories are described below and the items appear in Table A1. Readability of the scales are approximately at the 4th grade level; instructions and items can be read aloud to any individual who cannot read.

The parent form (PCSI-P) initially contained 26 items, with few modifications from the original 22-item PCS, other than rewording to allow use by a third-person rater (e.g., "Complains of headache" instead of "Headache"), and the addition of four observable signs: appears dazed or stunned, becomes confused with directions or tasks, appears to move in a clumsy manner, answers questions more slowly than usual. Responses were made on a 7-point (0–6) Guttman scale indicating the severity of the symptom. The following anchors were provided: 0 = Not a problem, 3 = Moderate problem, 6 = Severe problem.

The adolescent self-report form (PCSI-SR13, ages 13–18) also initially contained 26 items (22-item PCS plus the same four signs that were added to the parent form), and responses were rated for severity on the 7-point Guttman dimensional scale.

The older child self-report form for ages 8–12 years (PCSI-SR8) initially contained 25 items, adapted with simplified wording of symptoms (e.g., "Has your head hurt?" added to "Headache"). Additional modifications included dividing "Slowed Down" and "Visual Problems" into two symptoms each. Two new symptoms were added, assessing motor coordination and word selection problems. The response scale was simplified to a 3-point Guttman scale (0 = No, 1 = A little, 2 = A lot).

The younger child self-report form for ages 5–7 years (PCSI-SR5) initially contained 13 items, adapted to increase readability and concreteness, with a 3-point Guttman response scale. Items that used complex vocabulary, assessed subtle internal states, or were unlikely monitored by younger children (e.g., changes in sleep patterns) were not included.

Procedure

Participants completed the PCSI as part of the standard clinic or preinjury baseline visit. The self-report questionnaires were completed on a computer as part of the immediate postconcussion assessment and cognitive testing (ImPACT) battery (Lovell, Collins, Podell, Powell, & Maroon, 2000) or a battery of neurocognitive tests and symptom assessment for children ages 5–12 years (Gioia et al., 2009b). Items were read aloud to young children (ages 5–7) and to anyone who appeared to have difficulty reading independently. Parents completed their questionnaires in paper form while the child was being tested in another room.

Software and specifications. Descriptive statistics, reliability, and validity analyses were conducted using SAS v9.2 (SAS Institute, 2008). Factor analyses were completed using Mplus v4.21 (Muthén & Muthén, 2007), using WLSMV estimation for

Table 1. Demographic characteristics of the sample

	Concussion		Uninjured	
N	633		1,273	
	n	%	*n*	%
Age group				
5–7	91	14	198	16
8–12	315	50	690	54
13–18	227	36	385	30
Gender				
Male	421	67	903	71
Female	212	33	370	29
Race[a]				
White	285	45	942	74
Black	150	24	61	5
Other	47	7	59	5
Not reported/declined	151	24	211	17

Notes: [a]Significant difference between groups, $p < .05$.

Table 2. Injury characteristics of individuals with concussion

	13–18 year olds		8–12 year olds		5–7 year olds	
N	227		315		91	
	M	*SD*	*M*	*SD*	*M*	*SD*
Days since injury[a]	15.0	7.2	11.3	7.4	12.3	7.1
	n	%	*n*	%	*n*	%
Injury cause[a]						
Sports	177	78	130	41	9	10
Fall	22	10	83	26	36	40
Motor Vehicle	8	4	40	13	13	14
Other	20	9	58	18	16	18
Not reported	0	0	4	1	17	19
Had retrograde amnesia[a]						
Yes	56	25	56	18	9	10
No	159	70	227	72	62	68
Unknown/not reported	12	5	32	10	20	22
Recalled hit						
Yes	132	58	111	35	25	27
No	86	38	88	28	26	29
Unknown/not reported	9	4	116	37	40	44
Lost consciousness[a]						
Yes	33	15	89	28	18	20
No	183	81	192	61	55	60
Unknown/not reported	11	5	34	11	18	20
Had anterograde amnesia						
Yes	80	35	90	29	20	22
No	133	59	188	60	50	55
Unknown/not reported	14	6	37	12	21	23

Notes: [a]13–18 year group was seen significantly longer past injury; 13–18 year group more likely to be injured in sports, 5–12 year olds by falls; 13–18 year olds more likely to have retrograde amnesia; 5–12 year olds more likely to have lost consciousness.

the PCSI-SR5 and -SR8 (treating the 3-point scale as ordinal) and ML estimation for the PCSI-P and -SR13 (treating the 7-point response scale as continuous).

Results

Item Analysis

Frequency distribution of responses were examined for each item on the four versions of the PCSI, comparing rates of endorsement between the mTBI and uninjured groups to identify items with similar distributions for both groups, using *t*-tests and χ^2 analysis as appropriate. Across raters, headache and fatigue/tired were among the most commonly endorsed symptoms in both injured and uninjured individuals, with the exception of uninjured 5–7 year olds. On the PCSI-P, -SR8, and -SR13, all raters were least likely to rate the presence of numbness/tingling and vomiting (except uninjured children on the PCSI-SR8, where it was third). Self-report on the PCSI-SR5 and -SR8 was least likely to include endorsement of balance or coordination problems and visual problems (see Table 3 for means and proportions of responses to each item).

Parents of children with concussion rated every symptom except sleeping less as higher compared with ratings of uninjured children. Item endorsement between concussion and uninjured groups was significantly different on all items of the PCSI-SR13 except five. Responses on the -SR8 showed a similar pattern, rating all but four items higher for the concussion group. Ratings on the -SR5 were significantly different between groups on only four of the 13 items. Designations of which items were endorsed differentially between groups are presented in footnotes in Table 3.

Factor Structure

The initial factor structure to be examined included four content-based factors: physical/somatic, sleep/fatigue, emotional, and cognitive. Modifications (dropping from scale, moving to another factor) were based on: rate of endorsement in participants with

Table 3. Symptom endorsement by version and injury group

		Parent report		Self-report						
		PCSI-P (ages 5–18)		PCSI-SR13 (ages 13–18)			-SR 8 (8–12)		-SR5 (5–7)	
	Rating	UI	mTBI	UI	mTBI	Rating	UI	mTBI	UI	mTBI
Headache[a,b,c,d]	*M* (*SD*)	0.30 (0.82)	2.70 (2.07)	0.41 (0.86)	2.38 (1.93)					
	0 (%)	86	24	76	27	0 (%)	66	32	81	51
	1–3 (%)	14	39	23	39	1 (%)	31	39	11	28
	4–6 (%)	1	37	1	34	2 (%)	3	28	8	20
Nausea[a,b,c,d]	*M* (*SD*)	0.07 (0.39)	0.90 (1.57)	0.14 (0.55)	0.49 (1.10)					
	0	96	68	92	79	0	76	60	83	54
	1–3	4	22	8	18	1	22	30	14	30
	4–6	<1	10	<1	3	2	3	10	3	16
Vomiting[a,c]	*M* (*SD*)	0.02 (0.34)	0.24 (0.89)	0.02 (0.17)	0.03 (0.23)					
	0	99	91	98	99	0	96	89		
	1–3	<1	7	2	1	1	3	8		
	4–6	<1	2	0	0	2	1	3		
Balance problems[a,b]	*M* (*SD*)	0.01 (0.14)	0.91 (1.49)	0.15 (0.57)	0.61 (1.26)					
	0	99	64	91	75	0	90	64	83	76
	1–3	1	27	9	18	1	9	28	11	16
	4–6	0	9	1	6	2	1	8	6	8
Dizziness[a,b,c]	*M* (*SD*)	0.03 (0.28)	1.21 (1.72)	0.21 (0.64)	1.00 (1.54)					
	0	98	57	86	64	0	85	53	79	68
	1–3	2	31	12	26	1	14	37	13	16
	4–6	<1	12	1	11	2	1	10	9	16
Fatigue/tired[a,b,c]	*M* (*SD*)	0.14 (0.49)	1.93 (1.94)	0.70 (1.19)	1.94 (1.96)					
	0	90	36	65	39	0	55	34	56	47
	1–3	10	41	31	32	1	40	42	25	32
	4–6	<1	23	4	28	2	5	23	19	20
Difficulty falling asleep[a,c]	*M* (*SD*)	0.15 (0.58)	1.17 (1.76)	0.65 (0.25)	0.98 (1.71)					
	0	92	63	73	69	0	73	34		
	1–3	8	23	23	19	1	22	20		
	4–6	<1	14	4	12	2	5	16		
Sleeping more[a,b,c]	*M* (*SD*)	0.07 (0.37)	1.51 (1.91)	0.42 (0.99)	1.08 (1.81)					
	0	96	51	81	68	0	75	63		
	1–3	4	31	17	17	1	21	23		
	4–6	<1	18	2	15	2	4	15		
Sleeping less	*M* (*SD*)	0.08 (0.45)	0.53 (0.29)	0.46 (1.12)	0.46 (1.29)					
	0	96	82	81	85	0	76	74		
	1–3	4	13	15	9	1	21	19		
	4–6	<1	5	5	6	2	3	7		
Drowsiness[a,b,c]	*M* (*SD*)	0.11 (0.45)	1.30 (1.70)	0.47 (0.95)	1.70 (1.88)					
	0	93	53	75	45	0	70	43		
	1–3	7	34	24	36	1	27	40		
	4–6	<1	13	2	19	2	3	17		
Sensitivity to light[a,b,c]	*M* (*SD*)	0.04 (0.32)	1.27 (1.77)	0.14 (0.56)	1.25 (1.70)					
	0	98	57	92	59	0	83	63	80	73
	1–3	2	28	7	26	1	15	28	12	15
	4–6	<1	15	1	16	2	2	10	9	12
Sensitivity to noise[a,b,c]	*M* (*SD*)	0.04 (0.29)	1.22 (1.78)	0.07 (0.39)	0.94 (1.64)					
	0	98	60	96	69	0	83	66	72	64
	1–3	2	24	4	20	1	14	24	15	22
	4–6	<1	16	<1	11	2	3	9	13	15
Irritability[a,b,c,d]	*M* (*SD*)	0.20 (0.62)	1.45 (1.78)	0.37 (0.89)	0.94 (1.59)					
	0	88	47	81	67	0	67	57	80	66
	1–3	11	38	18	23	1	30	33	8	24
	4–6	1	15	2	10	2	3	10	12	9
Sadness[a,b,c]	*M* (*SD*)	0.08 (0.38)	0.92 (1.45)	0.17 (0.62)	0.50 (1.27)					
	0	95	63	91	83	0	77	74	78	66
	1–3	5	30	8	12	1	20	18	13	20
	4–6	<1	8	1	6	2	2	8	9	14

Continued

Table 3. *Continued*

		Parent report		Self-report						
		PCSI-P (ages 5–18)		PCSI-SR13 (ages 13–18)			-SR 8 (8–12)		-SR5 (5–7)	
	Rating	UI	mTBI	UI	mTBI	Rating	UI	mTBI	UI	mTBI
Nervousness[a,d]	*M* (*SD*)	0.07 (0.38)	0.58 (1.25)	0.40 (0.88)	0.48 (1.15)					
	0	96	76	77	79	0	69	63	83	65
	1–3	4	18	22	18	1	28	31	11	18
	4–6	<1	5	2	3	2	3	6	7	18
Feeling more emotional[a,b]	*M* (*SD*)	0.16 (0.59)	1.19 (1.72)	0.17 (0.59)	0.59 (1.38)					
	0	90	57	91	80					
	1–3	9	29	9	14					
	4–6	1	14	1	6					
Numbness or tingling[a]	*M* (*SD*)	0.02 (0.21)	0.28 (0.88)	0.15 (0.59)	0.13 (0.58)					
	0	99	88	92	93	0	66	70		
	1–3	1	10	8	6	1	32	25		
	4–6	<1	2	1	<1	2	2	4		
Moving slowly[c]										
						0	88	62		
						1	11	30		
						2	1	8		
Slowed down/thinking slowly[a,b,c]	*M* (*SD*)	0.06 (0.32)	1.44 (1.76)	0.22 (0.63)	1.40 (1.86)					
	0	96	48	87	57	0	85	56		
	1–3	4	36	13	26	1	14	32		
	4–6	<1	15	<1	17	2	1	11		
Mentally foggy/hard to think clearly[a,b,c]	*M* (*SD*)	0.02 (0.19)	1.25 (1.69)	0.18 (0.60)	1.41 (1.93)					
	0	98	53	90	58	0	84	57		
	1–3	2	35	10	19	1	15	31		
	4–6	0	12	<1	23	2	1	12		
Difficulty concentrating[a,b,c,d]	*M* (*SD*)	0.15 (0.55)	1.74 (1.90)	0.47 (1.07)	1.98 (2.05)					
	0	91	42	77	42	0	71	52	76	53
	1–3	9	39	20	29	1	26	36	15	32
	4–6	<1	19	3	29	2	3	13	9	15
Difficulty remembering[a,b,c]	*M* (*SD*)	0.09 (0.41)	1.32 (1.74)	0.29 (0.82)	1.47 (1.86)					
	0	94	50	85	51	0	76	46	68	56
	1–3	6	37	14	32	1	22	43	22	26
	4–6	<1	13	2	17	2	2	11	10	18
Visual problems/blurry vision[a,b,c]	*M* (*SD*)	0.03 (0.24)	0.74 (1.42)	0.13 (0.50)	0.55 (1.17)					
	0	99	72	92	77	0	91	80	85	77
	1–3	1	21	8	18	1	8	18	9	15
	4–6	<1	7	<1	5	2	1	2	6	8
Double vision										
						0	94	88		
						1	5	10		
						2	1	2		
Dazed[a,b]	*M* (*SD*)	0.02 (0.23)	0.69 (1.40)	0.05 (0.28)	1.22 (1.57)					
	0	99	74	97	49					
	1–3	1	19	3	40					
	4–6	<1	7	0	11					
Confused[a,b]	*M* (*SD*)	0.04 (0.27)	0.93 (1.54)	0.25 (0.67)	1.59 (1.68)					
	0	97	64	85	40					
	1–3	3	27	15	43					
	4–6	<1	9	<1	17					
Clumsy/coordination problems[a,b,c]	*M* (*SD*)	0.02 (0.20)	0.59 (1.24)	0.21 (0.70)	1.12 (1.60)					
	0	98	74	87	55	0	95	83		
	1–3	2	21	12	34	1	4	14		
	4–6	0	5	1	12	2	1	3		

Continued

Table 3. *Continued*

	Rating	Parent report PCSI-P (ages 5–18) UI	mTBI	Self-report PCSI-SR13 (ages 13–18) UI	mTBI	Rating	-SR 8 (8–12) UI	mTBI	-SR5 (5–7) UI	mTBI
Answers slowly/hard to find words[a,b,c]	*M* (*SD*)	0.01 (0.14)	0.98 (1.55)	0.16 (0.57)	1.76 (1.83)					
	0	99	60	90	37	0	78	65		
	1–3	1	31	10	42	1	20	30		
	4–6	0	9	<1	21	2	2	5		

Notes: IU = uninjured; mTBI = mild traumatic brain injury/concussion.

PCSI-parent (ages 5–18) uninjured $n = 1{,}037$, mTBI $n = 521$; -SR13 (ages 13–18) uninjured $n = 385$, mTBI $n = 223$; -SR8 (ages 8–12) uninjured $n = 669$, mTBI $n = 264$; -SR5 (ages 5–7) uninjured $n = 198$, mTBI $n = 74$.

Parent report and SR13 are on a 0–6 Guttman scale (0 = Not a problem, 3 = Moderate problem, 6 = Severe problem). Values presented are means/*SD* and percentages endorsing each grouping of categories.

SR5 and SR8 are on a 0–2 Guttman scale (0 = None, 1 = A little, 2 = A lot). Values are percentages endorsing each category.

Due to rounding, not all sets will add up to 100%.

Where two symptoms are separated by a slash (/), the first description refers to the wording of the item on the PCSI-P and -SR13, whereas the second describes the wording of the corresponding items on the -SR8 and -SR5.

[a]Parent ratings on the item were significantly higher in the mTBI group than the uninjured group.

[b]13–18 year olds' ratings were significantly higher in the mTBI group than the uninjured group.

[c]8–12 year olds' ratings were significantly higher in the mTBI group than the uninjured group.

[d]5–7 year olds' ratings were significantly higher in the mTBI group than the uninjured group.

concussion, difference between endorsement in concussion and uninjured groups, factor loadings and residual variances, and suggestions from Mplus modification indices. In each model, the factors were allowed to correlate, factor variance was fixed to 1.0, the unstandardized factor loading for the first item on each factor was fixed to 1.0, and residual covariances were fixed to 0.0. Modifications were made until either model fit was acceptable or the factors made theoretical sense and further modifications were not logical. Good model fit was defined as: the ratio of $\chi^2/df < 3.0$ (Kline, 2004); RMSEA or SRMR <0.06 for continuous scales and WRMR <0.90 for ordinal outcomes; and CFI >0.90 (Hu & Bentler, 1999). The factor structure was derived in the concussion sample and then applied to the corresponding uninjured sample.

Parent report. The initial model contained four factors of physical, cognitive, emotional and sleep symptoms, and this 26-item model did not meet suggested cutoffs on most measures (χ^2/df ratio = 6.96, RMSEA = 0.11, SRMR = 0.063, CFI = 0.81). Five items were dropped for low factor loadings (<0.3), several of which were also rarely endorsed by parents of children with concussion: vomiting, numbness/tingling, sleeping less, trouble falling asleep, and dazed/stunned. Modification indices suggested moving fatigue from the physical factor to the sleep/fatigue factor, which was supported by a stronger factor loading. Slowed down was dropped as it loaded equally well on the sleep/fatigue and cognitive factors, suggesting multidimensionality. None of the additional suggested modifications to the model made theoretical sense; e.g., placing more emotional on the physical factor, or loading clumsy on the cognitive factor. These changes improved the model fit slightly; suggested cutoffs were close or met on two metrics: $\chi^2/df = 5.63$, RMSEA = 0.094, SRMR = 0.051, and CFI = 0.89, and all factor loadings were strong (>0.50). The final model of the PCSI-P, with 20 symptoms across four factors, is presented in Table 4.

The final structure was applied to parents of uninjured participants. Not surprisingly given the low rate of item endorsement, model fit was rather poor, with no values meeting suggested cutoffs ($\chi^2/df = 8.03$, RMSEA = 0.082, SRMR = 0.065, CFI = 0.76), and multiple items loaded poorly.

Self-report 13–18. The initial 26-item model tested was identical to Model 1 for parents. Model fit was poor on all indices ($\chi^2/df = 3.19$, RMSEA = 0.098, SRMR = 0.070, CFI = 0.82). Similar to the parent PCSI, vomiting, numbness/tingling, sleeping less, and trouble falling asleep were dropped due to low factor loadings, and fatigue was moved to the sleep factor. No other suggested modifications made theoretical sense. The final model fit of the 21-item PCSI-SR13 improved on all indices, and three were within or near desired ranges ($\chi^2/df = 2.66$, RMSEA = 0.086, SRMR = 0.058, CFI = 0.90). All factor loadings were strong (>0.50; see Table 4).

The final structure was applied to 13 to 18-year olds uninjured participants. While all factor loadings were >0.30, model fit statistics did not reach suggested cutoffs for good fit ($\chi^2/df = 4.06$, RMSEA = 0.089, SRMR = 0.069, CFI = 0.81).

Self-report 8–12. The initial 25-item model tested was similar to Model 1 for parents and 13–18 year olds, with four latent factors specified (physical, cognitive, emotional, and sleep/fatigue). Fit of the initial model was fair ($\chi^2/df = 2.63$, RMSEA = 0.079, WRMR = 1.12, CFI = 0.93). As with the PCSI-P and -SR13, vomiting, numbness/tingling, sleeping less, and trouble falling

Table 4. Factor structure of four versions of the PCSI in individuals with concussion

	Factor loadings			
	Parent report	Self-report		
Factor/items	5–18	13–18	8–12	5–7
Physical symptoms				
Dizziness	0.76	0.75	0.71	0.72
Balance problems	0.75	0.67	0.82	–
Sensitivity to light	0.70	0.70	0.61	–
Sensitivity to noise	0.69	0.65	74	–
Headache	0.67	0.71	0.69	0.60
Clumsy	0.66	0.68	–	–
Nausea	0.60	0.58	0.58	0.72
Visual problems/blurry vision	0.58	0.65	0.69	–
Moving slowly		–	0.76	–
Cognitive symptoms				
Difficulty concentrating	0.87	0.87	0.91	0.79
Difficulty remembering	0.87	0.80	0.65	–
Mentally foggy/hard to think clearly	0.86	0.82	0.88	–
Confused	0.81	0.84	–	–
Answers slowly	0.81	0.82	–	–
Thinking slowly	–	0.82	0.88	–
Emotional symptoms				
Irritability	0.85	0.74	0.88	0.40
Feeling more emotional	0.83	0.87	–	–
Sadness	0.71	0.81	0.66	–
Nervousness	0.58	0.66	0.56	–
Fatigue symptoms				
Fatigue/tired	0.91	0.91	0.89	–
Sleeping more	0.83	0.55	–	–
Drowsiness	0.73	0.79	0.87	–

Notes: PCSI-parent (ages 5–18) $n = 521$; PCSI-SR13 (ages 13–18) $n = 223$; -SR8 (ages 8–12) $n = 264$; -SR5 (ages 5–7) $n = 74$.

asleep were dropped due to low endorsement rates and/or low factor loadings, and tired was moved to the sleep/fatigue factor. Four additional items were dropped due to factor loadings <0.3 and low rate of endorsement: Sleeping more, double vision, coordination problems, and word selection problems. The final 17-item model fit improved, as it was at or near suggested cutoffs on all values ($\chi^2/df = 2.10$, RMSEA = 0.065, WRMR = 0.88, CFI = 0.97), and all factor loadings were 0.56 or higher (see Table 4).

The same structure was applied to 8–12 year olds without injury. Model fit of the 17-item PCSI-SR8 was good ($\chi^2/df = 2.22$, RMSEA = 0.043, WRMR = 0.95, CFI = 0.95), and all factor loadings were >0.53.

Self-report 5–7. In the initial 13-item model, three factors (physical, cognitive, and emotional) were specified. Despite a relatively small sample size, model fit was acceptable on most indices ($\chi^2/df = 1.32$ and χ^2 not significant, RMSEA = 0.066, WRMR = 0.70, CFI = 0.96). All factor loadings were 0.4 or higher, though variance explained varied widely, ranging from 0.18 (sensitivity to light) to 0.80 (balance problems). Several items were dropped because they had low endorsement, poor differentiation between concussion and uninjured groups, and relatively lower factor loadings: balance problems, tiredness, sensitivity to light, sensitivity to noise, sadness, nervousness, difficulty remembering, and visual problems. The five remaining items were analyzed in a single factor solution. These five items were the most differentiating (particularly within the first 2 weeks after injury) and had the strongest factor loadings. Model fit was acceptable on one metric and close on two others ($\chi^2/df = 3.31$, χ^2 significant at $p = .01$, RMSEA = 0.18, WRMR = 0.72, CFI = 0.85), worse than the original partially due to the small number of items and presence of only one factor. The final five-item model for the PCSI-SR5 is presented in Table 4.

The five item, single factor structure was applied to 5–7 year olds without injury. Model fit was good by most standards ($\chi^2/df = 1.88$ and χ^2 not significant, RMSEA = 0.067, WRMR = 0.58, CFI = 0.97).

Reliability

Factor correlations. Correlations between factors were generally moderate and are presented in Table 5. As expected, most correlations were lower in the uninjured group than the concussion group, likely due in part to range restriction caused by low endorsement of many items in those without injury.

Table 5. Pearson's correlations between factors (mTBI below diagonal in bold; uninjured above)

	Physical symptoms	Cognitive symptoms	Emotional symptoms	Sleep symptoms
PCSI-parent				
Physical symptoms	–	0.37	0.36	0.28
Cognitive symptoms	**0.72**	–	0.42	0.29
Emotional symptoms	**0.63**	**0.60**	–	0.37
Fatigue symptoms	**0.69**	**0.68**	**0.54**	–
PCSI-SR13				
Physical symptoms	–	0.69	0.51	0.51
Cognitive symptoms	**0.73**	–	0.58	0.53
Emotional symptoms	**0.52**	**0.45**	–	0.41
Fatigue symptoms	**0.65**	**0.69**	**0.44**	–
PCSI-SR8				
Physical symptoms	–	0.62	0.41	0.43
Cognitive symptoms	**0.74**	–	0.47	0.41
Emotional symptoms	**0.57**	**0.47**	–	0.34
Fatigue symptoms	**0.59**	**0.57**	**0.40**	–

Notes: Parent 5–18 uninjured $n = 1{,}037$, mTBI $n = 521$; -SR13 uninjured $n = 385$, mTBI $n = 223$; -SR8 uninjured $n = 669$, mTBI $n = 264$; -SR5 uninjured $n = 198$, mTBI $n = 74$.

Internal consistency. Using the final item sets and empirically derived factor structures, a PCSI Total Symptom score was calculated for all forms, and physical, cognitive, emotional, and fatigue symptom subscale scores for all forms but the PCSI-SR5. Within the mTBI sample, internal consistency was generally strong for each score (see Table 6). For the PSCI-P, subscale α values ranged from 0.83 to 0.92, with $\alpha = 0.94$ for the PCSI total symptom score. Reliability was strong for the PCSI-SR13, ranging from $\alpha = 0.79$–0.93 for the subscales and $\alpha = 0.94$ for the PCSI total symptom score. A similar pattern emerged for the PCSI-SR8, ranging from $\alpha = 0.62$ to 0.84 for the subscales and $\alpha = 0.90$ for the PCSI total symptom score. Internal consistency was somewhat lower on the PCSI-SR5 ($\alpha = 0.67$), likely due to smaller sample size and fewer items (Weng, 2004). Within the uninjured sample, internal consistency was uniformly lower for the symptom subscales, but values for the PCSI total symptom score were generally strong (see Table 6).

Test–retest reliability. Two sets of ratings were available for a subset of the uninjured sample, obtained during various normative data collection efforts. Retest parent reports were not collected due to logistic limitations of data collection. The test–retest interval ranged from 3 to 14 days. Test–retest reliability was assessed using Pearson's r and intraclass coeffecients (ICCs; two-way random effects, absolute agreement, average measures). Reliability of total symptom scores was moderate for the PCSI-SR5 and higher for the -SR8 and -SR13 (see Table 7), with lower values for subscales. The rate of symptom endorsement was consistent across occasions, as paired t-tests indicated that the only significant difference between time one and time two ratings was on the PCSI-SR8, emotional symptoms (time two ratings were lower, $p = .003$, Cohen's $d = 0.30$) (see Table 8 for descriptive statistics for the two timepoints).

Rating concordance. We analyzed rater concordance between parent and self-report (uninjured $n = 1016$ pairs, mTBI $n = 447$ pairs), both on the item level and on the symptom subscales. For individual items, we compared ratings on common items using t-tests and correlations (13–18 year olds) and Kappa coefficients (5–12 year olds). To compare across parent- and self-report for 5–12 year olds, who had different response scales, items were dichotomized into not endorsed (response of 0) or endorsed (1 or greater). The family-wise error rate for each age group was maintained at $p < .05$ for each scale using Bonferroni correction.

For 8–12 and 13–18 year olds, parents of individuals with concussion were more likely to endorse items than the patients themselves, and the reverse was true for uninjured individuals. Children aged 5–7 were more likely than parents to endorse most items regardless of injury status. Among 13–18 year olds with concussion, ratings on each item were at least moderately correlated between raters (r range 0.24–0.65), whereas among 13–18 year olds without concussion, only one item was correlated above $r = 0.30$. The same pattern held for younger children, such that Kappa coefficients for each item were >0.30 in individuals with concussion but almost uniformly <0.30 for items rated by uninjured individuals.

We also computed Pearson's correlations between parent- and self-report subsymptom totals. The pattern was similar within each age group, such that correlations were moderate to large for individuals with concussion, but much lower in those who were uninjured (see Table 9). Physical and cognitive symptoms were the most highly correlated, with emotional and fatigue symptoms slightly lower.

Table 6. Internal consistency for each version of the PCSI

	Parent report		Self-report					
	5–18		13–18		8–12		5–7	
	Conc	UI	Conc	UI	Conc	UI	Conc	UI
PCSI total symptom score	0.94	0.79	0.94	0.90	0.90	0.85	0.67	0.56
Physical symptom score	0.86	0.45	0.86	0.77	0.81	0.74	–	–
Cognitive symptom score	0.92	0.68	0.93	0.82	0.84	0.71	–	–
Emotional symptom score	0.83	0.76	0.85	0.78	0.62	0.63	–	–
Fatigue symptom score	0.87	0.69	0.79	0.53	0.79	0.70	–	–

Notes: PCSI-parent (ages 5–18) uninjured $n = 1{,}037$, mTBI $n = 521$; PCSI-SR13 (ages 13–18) uninjured $n = 385$, mTBI $n = 223$; -SR8 (ages 8–12) uninjured $n = 669$, mTBI $n = 264$; -SR5 (ages 5–7) uninjured $n = 198$, mTBI $n = 74$. mTBI = mild traumatic brain injury/concussion; UI = uninjured. Statistics presented are Cronbach's alpha.

Table 7. Test–retest reliability coefficients of uninjured self-report by age group (3–14 days retest interval)

Scale	Form name (ages in years)					
	PCSI-SR13 (13–18)[a]		-SR8 (8–12)[b]		-SR5 (5–7)[c]	
	ICC	Pearson	ICC	Pearson	ICC	Pearson
Total	0.79	0.66	0.89	0.81	0.65	0.48
Physical	0.64	0.47	0.89	0.80	–	–
Cognitive	0.76	0.61	0.82	0.70	–	–
Emotional	0.64	0.47	0.77	0.63	–	–
Fatigue	0.69	0.53	0.73	0.57	–	–

Notes: Reliability coefficients calculated using the ICC (two-way random, absolute agreement, average measures) and Pearson's r. Retest intervals: -SR5 $M = 7.48$, $SD = 1.8$, range 6–14; -SR8 $M = 7.64$, $SD = 2.0$, range = 5–14; -SR13 $M = 6.20$, $SD = 1.61$, range = 3–8.
[a] $n = 102$.
[b] $n = 81$.
[c] $n = 52$.

Table 8. Pearson's correlations of ratings between parent- and self-report, by age group and injury group

	PCSI-parent	
	mTBI	Uninjured
PCSI-SR13 (ages 13–18)		
PCSI total	0.65	0.13
Physical symptom	0.62	0.17
Cognitive symptom	0.62	0.05*
Emotional symptom	0.49	0.23
Fatigue symptom	0.58	0.17
PCSI-SR8 (ages 8–12)		
PCSI total	0.56	0.16
Physical symptom	0.61	0.17
Cognitive symptom	0.49	0.18
Emotional symptom	0.43	0.13
Fatigue symptom	0.34	0.11
PCSI-SR5 (ages 5–7)		
PCSI total	0.44	0.18

Notes: PCSI-SR13 uninjured $n = 313$, mTBI $n = 217$; -SR8 uninjured $n = 555$, mTBI $n = 196$; -SR5 uninjured $n = 148$, mTBI $n = 36$.
*$p > .05$.

Rank-order assessment of rater concordance. Concordance between reporters of the PCSI was also examined by comparing the rank order of symptom frequencies of the parent and self-report PCSI for the concussion and uninjured groups using Spearman's rho (r_s). The frequency of symptom reports (from Table 3) was rank ordered for each of the reporters. In the uninjured sample, there were strong relationships between the PCSI-P and -SR13 ($r_s = 0.59$, $p = .006$) and -SR8 ($r_s = 0.90$, $p < .001$). Similarly in the

Table 9. Classification statistics from discriminant function analysis

	Ages 13–18			Ages 8–12			Ages 5–7		
	Self	Parent	Both	Self	Parent	Both	Self	Parent	Both
Sensitivity	0.51	0.60	0.61	0.56	0.63	0.62	0.50	0.47	0.56
Specificity	0.89	0.89	0.89	0.79	0.97	0.97	0.83	1.00	0.97
PPV	0.82	0.97	0.98	0.73	0.96	0.96	0.75	1.00	0.95
NPV	0.64	0.71	0.72	0.64	0.72	0.72	0.63	0.65	0.69
+ Likelihood	4.63	35.00	53.00	2.66	24.60	24.40	3.00	–[a]	20.00
− Likelihood	0.55	0.40	0.40	0.56	0.38	0.39	0.60	0.53	0.46
Odds ratio	8.35	86.74	134.06	4.74	64.36	62.98	5.00	–[a]	43.75
Classification accuracy	70%	79%	80%	67%	80%	80%	67%	74%	76%
Area under the curve	0.71	0.88	0.85	0.71	0.91	0.89	0.78	0.91	0.90

Notes: Sensitivity, specificity, odds ratios, classification accuracy, and area under the curve. PCSI-SR13 (ages 13–18) $n = 348$; -SR8 (ages 8–12) $n = 392$; -SR5 (ages 5–7) $n = 72$; base rate = 0.50.
PPV = positive predictive value; NPV = negative predictive value.
[a]Could not be computed because the number of false positives was zero.

concussion sample, parents ratings were strongly correlated with rankings on the -SR13 ($r_s = 0.53$, $p = .02$) and the -SR8 ($r_s = 0.86$, $p < .001$). Ratings on the -SR13 and -SR8 were strongly related to each other for the uninjured ($r_s = 0.77$, $p = .001$) and the concussion samples ($r_s = 0.89$, $p < .001$). The symptom ratings on the -SR5 did not exhibit significant relationships with the other parent and self-report ratings in either the uninjured or concussion groups, possibly due to there being only five items in common.

Validity

Convergent. Convergent validity was assessed by examining rank orders of the PCSI symptoms relative to the same items of a similar symptom checklist that is part of a larger standardized assessment designed for use in initial triage postconcussion, the acute concussion evaluation (Gioia, Collins, & Isquith, 2008). This previously validated checklist was administered to adolescents and to parents of children with concussion, and a rank ordering of symptom frequency across all reporters was presented. Within those with concussion, there were significant relationships with the PCSI-P (17 items, $r_s = 0.93$, $p < .001$), PCSI-SR13 (18 items, $r_s = 0.86$, $p < .001$), and PCSI-SR12
(16 items, $r_s = 0.88$, $p < .001$), but not with the PCSI-SR5 (five items, $r_s = 0.60$, $p = .29$).

Classification analyses. Discriminant function analyses were conducted on an age and gender-matched subset of the uninjured and mTBI groups (13–18 year olds, $n = 174$ per group; 8–12 year olds, $n = 196$ per group; 5–7 year olds, $n = 36$ per group) to predict group membership. The discriminant functions were first run for PCSI-SR alone, PCSI-P alone, and then the combination of parent- and self-report, yielding a 2 × 2 contingency table reflecting the proportions of injured and non-injured children correctly and incorrectly classified at optimal cut points. Table 9 presents the results of the classification analysis, including sensitivity, specificity, predictive values, likelihood ratios, odds ratios, classification accuracy and area under the curve.

Across all age groups, parent report had better classification statistics than self-report, and the combination of parent and self-report was similar to that of parent report alone. Specificity was generally good (range 0.79–1.0) and was higher than sensitivity (range 0.47–0.63). Positive predictive values were stronger than negative predictive values, though it should be noted that predictive values cannot be generalized to samples with a different base rate (50% in this subsample). Positive likelihood ratios were all >1.0, and negative likelihood ratios were all well <1.0. Classification accuracy was 67–70% for self-report alone, and 74–80% for parent report and combined report.

Discussion

This study examined the content, factor structure, three forms of reliability (internal consistency, rater concordance, and test–retest), and convergent validity of four forms of the PCSI, a postconcussion symptom questionnaire specifically adapted for children, adolescents, and their parents. The PCSI items are developmentally appropriate, and items that were retained assist in differentiating concussed from non-concussed children. The PCSI has three forms for children of different ages (5–7, 8–12, and 13–18 years), and a companion parent report. Examining the psychometric properties of the PCSI fulfills an important need to have psychometrically sound pediatric concussion symptom measures for both sets of informants, and across the developmental spectrum. The analyses of items produced four versions of the PCSI, with 5 items for children 5–7 years (PCSI-SR5), 17 items for children 8–12 years (PCSI-SR8), 21 items for adolescents 13–18 years (PCSI-SR13), and 20 items for parent report (PCSI-P).

Implications of Findings

Our analyses support those of previous studies (e.g., Randolph et al., 2009) in that there are several symptoms that, while sometimes present after a concussion, are not endorsed at a significantly higher rate than before injury or do not covary with the majority of the other symptoms (e.g., numbness/tingling, vomiting, trouble falling asleep). These items may still be relevant for an individual patient, so they should be incorporated into the clinical interview with any patient with concussion. Specifically, vomiting or numbness/tingling in the acute postinjury period may indicate a more severe neurological problem that warrants follow-up. Sleep onset or maintenance problems may be more prevalent and discerning in a less acute sample (these analyses were limited to individuals within 30 days of concussion). For example, a disrupted sleep cycle might be a delayed effect of concussion and therefore more important to assess later in recovery. In addition, some of these rarely endorsed symptoms could be used as validity items. For example, vomiting reported several weeks from the injury could be a marker of significant anxiety or of an unrelated, as yet unidentified illness, whereas numbness/tingling reported for the first time several weeks after an injury could raise concern for somatization.

Results of our analyses also supported the recommendation to query fewer symptoms when surveying younger children. The lack of support for using additional items is likely related to developmental differences in ability to self-rate these types of experiences. For example, questions assessing sleep habits are better answered by parents than young children. The resulting PCSI scales therefore contain only the most relevant items for the developmental abilities of each respondent, a level of analysis that has not previously been undertaken for children's self-report concussion symptom scales. The resulting PCSI-SR5 is less strong psychometrically than the older children's and parents' version, suggesting that some caution needs to be used in interpretation of self-report in children this young. We do not believe that any of the self-report versions should be used in isolation, as parent report is an important accompaniment, but this is especially true in young children. The five-symptom inventory is therefore provided as a guideline for the most useful symptoms to query for this age range.

The factor structure of items was consistent with previous research on postconcussion symptom reporting, with evidence for physical, fatigue, emotional, and cognitive symptom factors (Axelrod et al., 1996; Ayr et al., 2009; Bohnen et al., 1995; Cicerone & Kalmar, 1995; Piland et al., 2003, 2006), providing additional evidence that these are the key types of symptoms experienced across various ages. The finding that model fit was not as good for uninjured individuals indicates that these particular symptoms do not tend to co-occur when there has been no concussion. For example, uninjured children with chronic headaches do not necessarily also experience balance problems, and children with attention problems do not also commonly experience being slowed down. Relatedly, internal consistency of subscales and total scores was higher in those with concussion, though overall internal consistency values were still relatively strong in both groups ($r = 0.79$–0.90). The other reason that fit was poor, particularly in parents and older children, is that there was a very low rate of endorsement of most symptoms, restricting the range of item covariances and limiting how well the models could fit.

Test–retest reliability of the self-report scales across a 2-week retest interval in uninjured individuals was moderately high, particularly in teens and older children. Test–retest has only been assessed on a few concussion symptom scales, and values have ranged from $r = 0.24$ over 1 year (Iverson & Goetz, 2004) to ICCs of 0.88–0.93 across 45 days (Mailer, Valovich-McLeod, & Bay, 2008). The magnitude of 2-week test–retest coefficients in this sample were in between (r range = 0.65–0.89). While test–retest for parent report on the PCSI remains to be assessed, there is promising support for reliability in children and adolescents without concussion. Such stability of ratings over time provides an initial level of support for use of the scale in individuals with concussion to assess meaningful change over time.

In individuals with concussion, parent–child concordance was low to moderate for individual symptoms, but moderate to strong for the subscales and total scale, which underscores that the two reports are not redundant but rather complimentary. As with other types of behavioral ratings, we do not expect perfect concordance. Parents may interpret behaviors differently than children experience them, or they may notice problems the children themselves do not (e.g., irritability or balance problems). Similarly, children may experience symptoms that are not displayed outwardly (e.g., nervousness). These varying perspectives in symptom manifestation can be helpful for treatment planning. Examining ratings from both sources can help identify where misunderstandings may occur, such as a child who is still experiencing significant headaches but has stopped telling their parent, or a child who is acting impatient and short tempered without realizing it.

One remarkable pattern was the low rate of endorsement of many of the items by parents of individuals without concussion, compared with self-report. While we would not expect a high level of symptom endorsement in those without an injury, it was striking that 63% of parents on the PCSI-P rated absence of any symptoms (compared with ~20% for on the -SR8 and -SR13 and 47% on the -SR5). It is possible that parents are less aware of their children's symptoms when there is no reason to take note of them or for the child to discuss how they feel (i.e., in the absence of illness or injury). The implications are that, especially for parents, a preinjury rating form may not be the best way to capture "typical" symptoms. Some groups have used retrospective preinjury ratings (e.g., Yeates et al., 2009), which involves rating preinjury symptoms shortly after the injury and may result in higher endorsement rates, but this approach has not yet been validated.

Classification analyses provided additional validity information by determining, among other statistics, the sensitivity and specificity of the scales. We used a base rate of 50% in this study so that we could match the samples on age and gender, so it is important to note that some of the calculated values would not apply in settings where the prevalence of concussion is much higher or lower. While specificity, sensitivity, and likelihood ratios are not base rate dependent, predictive values are. In a specialty clinic setting, where the base rate of concussion is expected to be much >50%, the current PPV and NPV are misleading. For example, in a clinic where the baserate of concussion is 90%, the PPV would be higher (0.90) and NPV would be lower (0.17). Estimates for any given setting can be calculated using our obtained sensitivity and specificity if the base rate is known (see equations presented in Slick, 2006).

The finding that parent report was more discriminating than self-report needs to be interpreted with caution, given that the ratings of parents of uninjured individuals may be an underestimate. This bias may have artificially inflated the classification rates for parent and therefore combined report, so these figures should not necessarily be taken as evidence that parents are better at reporting than children/adolescents. Overall, however, the results do suggest that high PCSI ratings were likely to be mTBI cases, but low ratings were more likely to be misclassified. This latter finding is consistent with research indicating that symptoms may resolve more quickly than other postinjury effects, such as neurocognitive testing (e.g., Broglio et al., 2007; Covassin et al., 2010; Fazio et al., 2007), and underscores the need for multi-faceted assessment in order to determine recovery.

Limitations and Future Directions

A few limitations should be noted. First, the concussion sample was referred for outpatient clinical evaluation, not recruited, so may not be representative of the larger population of individuals 5–18 years who sustain concussion because many do not seek treatment. The sample does, however, cover a wide range of ages and includes a diverse group of sports and non-sports injuries. As with any factor analytic study, cross-validating the PCSI forms in additional samples of both injured and uninjured children (particularly on the -SR5) will be important. The short range of retest (up to 14 days) in this study provides initial support for stability of ratings in the absence of concussion, and longer intervals should be explored. In addition, test–retest reliability in parent report should be studied. Alternative means of assessing preinjury report should be studied, particularly retrospective preinjury reports, to determine if this might present a less biased view of parent report.

With a sound factor structure and demonstrated psychometric properties, the symptom subscale and total symptom scores of the four PCSI forms can be used in future analyses to better characterize the effects of concussive injury in children and adolescents. The logical next step is to evaluate the use of each version of the PCSI in serial assessments of children and adolescents with concussion, to determine its utility in tracking recovery. Analyses of reliable change and standardized regression-based change can also be undertaken to provide guidance on when changes in ratings over time would be considered statistically significant.

Future research should also be undertaken to relate symptom reports to other injury variables to build evidence for predictive and concurrent validity of the four versions of the PCSI. For example, there is value in understanding whether certain clusters of symptoms correlate with preinjury factors (e.g., presence of emotional or cognitive problems, gender, age, etc.), which would help predict the types of symptoms an individual might report. Concurrent validity should be examined with other postinjury difficulties (e.g., exertional effects, cognitive performance). Predictive validity should be examined to determine whether certain symptom clusters predict length of recovery or type of intervention needed. In addition, different subscales may have different rates of recovery, and thus different points in time where clinical attention and intervention may be most needed. Therefore, future research should examine the structure of symptoms and their relationship to other assessment results over time.

Conflict of Interest

CGV and GAG are co-authors on an upcoming neurocognitive test that utilizes the 5–7 and 8–12 year olds PCSI.

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Appendix

Table A1. Items on the PCSI by age range/rater

Parent report	Self-report		
(ages 5–18)	-SR13 (ages 13–18)	-SR8 (ages 8–12)	-SR5 (ages 5–7)
Complained of headaches[a]	Headache[a]	Have you had headaches? Has your head hurt?[a]	Have you had headaches? Has your head hurt?[a]
Complained of nausea[a]	Nausea[a]	Have you felt sick to your stomach or nauseous?[a]	Have you felt sick to your stomach or like you were going to throw up?[a]
Vomited	Vomiting	Have you thrown up?	
Had balance problems[a]	Balance problems[a]	Have you had any balance problems or have you felt like you might fall when you walk, run or stand?[a]	Have you felt like you might fall when you walk, run, or stand?
Appeared or complained of dizziness[a]	Dizziness[a]	Have you felt dizzy? (like things around you were spinning or moving)[a]	Have you felt dizzy? (like things around you were spinning or moving)[a]
Appeared more tired or fatigued[a]	Fatigue[a]	Have you felt more tired than usual?[a]	Have you felt more tired than usual?
Had trouble falling asleep	Trouble falling asleep	Has it been harder than usual for you to fall asleep?	
Was sleeping more than usual[a]	Sleeping more than usual[a]	Have you been sleeping more than usual?	
Was sleeping less than usual	Sleeping less than usual	Have you been sleeping less than usual?	
Appeared drowsy[a]	Drowsiness[a]	Have you felt more drowsy or sleepy than usual?[a]	
Was sensitive to light[a]	Sensitivity to light[a]	Have bright lights bothered you more than usual? (like when you were in the sunlight, when you looked at lights, or watched TV)[a]	Have bright lights bothered you more than usual? (like when you were in the sunlight, when you looked at lights, or watched TV)
Was sensitive to noise[a]	Sensitivity to noise[a]	Have loud noises bothered you more than usual? (like when people were talking, when you heard sounds, watched TV, or listened to loud music)[a]	Have loud noises bothered you more than usual? (like when people were talking, when you heard sounds, watched TV, or listened to loud music)
Was irritable[a]	Irritability[a]	Have you felt grumpy or irritable? (like you were in a bad mood)[a]	Have you felt grumpy? (like you were in a bad mood)[a]
Appeared sad[a]	Sadness[a]	Have you felt sad?[a]	Have you felt sad?
Acted nervous[a]	Nervousness[a]	Have you felt nervous or worried?[a]	Have you felt nervous or worried?
Acted more emotional[a]	Feeling more emotional[a]		
Had or complained of numbness or tingling	Numbness or tingling	Have any of your body parts tingled or felt numb? (like when your foot falls asleep)	
		Have you felt like you are moving more slowly?[a]	
Acted or appeared slowed down	Feeling slowed down[a]	Have you felt like you are thinking more slowly?[a]	
Acted or appeared mentally foggy[a]	Feeling mentally foggy[a]	Has it been hard to think clearly?[a]	
Had difficulty concentrating[a]	Difficulty concentrating[a]	Has it been hard for you to pay attention to what you are doing? (like homework or chores, listening to someone, or playing a game)[a]	Has it been hard for you to pay attention to what you are doing? (like homework or chores, listening to someone, or playing a game)[a]
Had difficulty remembering[a]	Difficulty remembering[a]	Has it been hard for you to remember things? (like things you heard or saw, or places you have gone)[a]	Has it been hard for you to remember things? (like things you heard or saw or places you have gone)
Had or complained of visual problems (blurry, double vision)[a]	Visual problems (double vision, blurring)[a]	Have things looked blurry?[a]	Have things looked fuzzy or blurry?
		Have you been seeing double?	
Appeared dazed or stunned	Feel dazed or stunned		
Became confused with directions or tasks[a]	Get confused with directions or tasks[a]		
Appeared to move in a clumsy manner[a]	Move in a clumsy manner[a]	Has it been harder for you to tie your shoelaces, use zippers, write or draw?	
Answered questions more slowly than usual[a]	Answer questions more slowly than usual[a]	Has it been hard for you to think of the right words to say?	

Notes: [a]Retained in final scale.

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