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Sport Concussion Assessment Tool Symptom Inventory: Healthy and Acute Postconcussion Symptom Factor Structures

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Context: Previous researchers have examined factor structures for common concussion symptom inventories. However, they failed to discriminate between the acute (<72 hours) and subacute (3 days–3 months) periods after concussion. The Sport Concussion Assessment Tool (SCAT) is an acute assessment that, when compared with other concussion symptom inventories, includes or excludes symptoms that may result in different symptom factors.

Objective: The primary purpose was to investigate the symptom factor structure of the 22-item SCAT symptom inventory in healthy, uninjured and acutely concussed high school and collegiate athletes. The secondary purpose was to document the frequency of the unique SCAT symptom inventory items.

Design: Case series.

Setting: High school and college.

Patients or Other Participants: A total of 1334 healthy, uninjured and 200 acutely concussed high school and collegiate athletes.

Main Outcome Measure(s): Healthy, uninjured participants completed the SCAT symptom inventory at a single assessment. Participants in the acutely concussed sample completed the SCAT symptom inventory within 72 hours after concussion. Two separate exploratory factor analyses (EFAs) using a principal component analysis and varimax extraction method were conducted.

Results: A 3-factor solution accounted for 48.1% of the total variance for the healthy, uninjured sample: cognitive-fatigue (eg, feeling "in a fog" and "don't feel right"), migraine (eg, neck pain and headache), and affective (eg, more emotional and sadness) symptom factors. A 3-factor solution accounted for 55.0% of the variance for the acutely concussed sample: migraine-fatigue (eg, headache and "pressure in the head"), affective (eg, sadness and more emotional), and cognitive-ocular (eg, difficulty remembering and balance problems) symptom factors.

Conclusions: The inclusion of unique SCAT symptom inventory items did not alter the symptom factor structure for the healthy, uninjured sample. For the acutely concussed sample, all but 1 unique SCAT symptom inventory item (neck pain) loaded onto a factor.

Key Words: factor analysis, symptoms, concussion, traumatic brain injury

Key Points

- Symptom factors for the healthy, uninjured participants were cognitive-fatigue, migraine, and affective.
- Symptom factors for the acutely concussed participants were migraine-fatigue, affective, and cognitive-ocular.
- Among the acutely injured group, 54.5% reported neck pain within 72 hours of concussion.
- Understanding acute postinjury symptom factors may aid in the identification of clinical profiles and appropriate treatment strategies after concussion.

After a concussion, it is common for athletes to experience a wide array of cognitive, emotional, somatic, and sleep symptoms.[1] Postconcussion symptoms receive heightened attention due to their direct effect on activities of daily living and are often considered by health care professionals when diagnosing and managing athletes with concussion.[2] Headache, dizziness, and difficulty concentrating are the most commonly reported symptoms after concussion.[3] However, due to the heterogeneous nature of concussion, symptoms may vary from athlete to athlete. To better conceptualize symptom evaluations and identify patterns in symptom reporting after concussion, researchers[1,4–10] have used factor analytic approaches. Establishing symptom factors from these approaches can assist health care professionals in accurately assessing, managing, and treating athletes with concussion.

Identifying symptom factors provides several well-documented clinical advantages. First, examining preinjury symptom factors may provide insight into postinjury symptom reporting. Health care professionals should be cognizant of preinjury symptom endorsement, as it may influence the assessment and management of concussion. For example, concussed athletes with increased preinjury somatization reported greater symptom severity throughout recovery and took longer to recover.[11] Second, identifying postinjury symptom factors may help increase the clarity of the symptoms reported after concussion. Moreover, symptom factors may help identify concussion clinical profiles,[12] which can aid health care professionals in implementing guided treatment approaches.[13] For instance, increased symptoms in the somatic symptom factor (eg, vomiting and numbness) within the first week of injury predicted increased vestibular and ocular-motor symptom provocation.[12] Using existing exploratory and confirmatory factor analyses, investigators have examined the symptom factor structures of the Post-Concussion Symptom Scale (PCSS),[1,7,8] the Graded Symptom Checklist,[10] the Rivermead Post Concussion Questionnaire,[4,5] and the Head Injury Scale.[9] In the first preliminary study,[1] researchers assessed the symptom factor structure of the PCSS in concussed athletes within 7 days of diagnosis. Exploratory factor analysis revealed a 4-factor solution: cognitive, sleep problems, emotionality, and somatic symptom factors. In a subsequent study, Kontos et al[7] reevaluated the PCSS factor structure in independent samples of healthy athletes at baseline and concussed athletes within 7 days of injury. Four-factor solutions were present in the baseline sample (cognitive-sensory, sleep-arousal, vestibular-somatic, and affective) and the postconcussion sample (cognitive-migraine-fatigue, affective, somatic, and sleep).[7] However, these studies[1,7] were limited by the lack of discrimination between the *acute period*, defined by the National Institute of Neurological Disorders and Stroke and Sport Related Concussion working group[14] as $\leq$ 72 hours after a concussion, and the *subacute period*, defined as $>$ 72 hours to 3 months after a concussion. Previous authors[15] suggested that symptoms evolve throughout concussion recovery, and therefore, identifying symptom factors in the acute period after concussion is important.

The Sport Concussion Assessment Tool (SCAT) is a widely endorsed instrument for evaluating patients with concussion.[16] According to the Concussion in Sport Group consensus,[17] the SCAT is most clinically useful immediately after injury and loses clinical utility after 3 to 5 days postinjury. Recently, the National Institute of Neurological Disorders and Stroke and Sport Related Concussion working group[18] recognized the SCAT symptom inventory as a common data element in the acute period after concussion. However, the 22-item SCAT symptom inventory is not equivalent to the PCSS. Specifically, the SCAT symptom inventory contains 5 symptoms that are not included in the PCSS: "pressure in the head," neck pain, blurred vision, "don't feel right," and confusion.[17] In addition, nausea and vomiting are combined on the SCAT symptom inventory.[17] The inclusion or exclusion of these symptoms might result in different symptom factors than those identified previously.[1,4–10] Thus, given the clinical value of identifying symptom factors combined with the recommended use of the SCAT and its symptom inventory for the acute assessment of concussion, determining an acute symptom factor structure of this assessment is warranted. Moreover, the frequency of the items ("pressure in the head," neck pain, blurred vision, "don't feel right," and confusion) is unknown, and their contribution to symptom loading is understudied. The primary purpose of our study was to investigate the symptom factor structure of the 22-item SCAT symptom inventory in healthy, uninjured and acutely concussed high school and collegiate athletes. The secondary purpose was to document the frequency of the unique SCAT symptom inventory items ("pressure in the head," neck pain, blurred vision, "don't feel right," confusion) in healthy, uninjured and acutely concussed high school and collegiate athletes.

METHODS

Study Design

We used a case series research design.

Participants

Recruits were high school and collegiate athletes (aged 12–24 years) from 2 Midwestern regions of the United States. Data were collected from 14 high schools, 4 collegiate institutions, and 2 youth sports programs between 2013 and 2018. Healthy participants were recruited from 14 high schools, 2 collegiate institutions, and 2 youth sports programs. They were tested at baseline (ie, preseason) or throughout the year as the healthy control group. Participants were included in the healthy sample if they did not report having a concussion at the time of testing. Those in the acutely concussed sample were diagnosed with a concussion by a health care professional and completed the SCAT within the acute time period after injury. We defined the *acute time period* as $\leq$ 72 hours of injury. Acute postinjury participants were recruited from 10 high schools and 4 collegiate institutions. Regardless of group, volunteers were excluded if they did not speak English as their primary language.

Operational Definition of Concussion

Concussion was defined as an altered mental status induced by biomechanical forces that resulted in various clinical signs and symptoms that could not be explained by another injury.[17] Concussions were assessed by health care providers using the following criteria: (1) observed or reported mechanism of injury (eg, direct blow to the head, face, neck, or elsewhere on the body) and (2) the presence of 1 or more on-field signs (eg, disorientation or confusion, loss of consciousness, balance difficulties, or amnesia) or symptoms (eg, dizziness, nausea, or headache) or any impairment on sideline assessment (eg, SCAT).

Sport Concussion Assessment Tool

Demographic information (eg, date and time of injury, sex, years of education, and previous medical history) were collected via the athlete background section of the SCAT. Symptoms were assessed using the SCAT symptom inventory. Participants were instructed to report symptoms based on how they felt at the moment of testing. The SCAT symptom inventory consists of a 22-item, 7-point Likert scale ranging from *none* (0) to *severe* (6).[16] Face validity has been established based on expert agreement,[19] and the SCAT symptom inventory has been shown to discriminate between healthy and concussed athletes.[17]

Table 1. Demographic Information for the Healthy, Uninjured (n = 1334) and Acute Postinjury (n = 200) Samples

Variable	Healthy, Uninjured, n (%) or Mean ± SD	Acute Postinjury, n (%) or Mean ± SD	*P* Value
Sex[a]			>.001
Male	694 (52.1)	132 (66.0)	
Female	637 (47.9)	68 (34.0)	
Medical history			
Previous concussion[a]	255 (19.1)	73 (36.5)	>.001
Migraine	91 (6.8)	17 (8.7)	.63
Attention-deficit/hyperactivity or learning disorder	94 (7.0)	14 (9.9)	.49
Depression or anxiety	49 (3.7)	10 (5.1)	.57
Sport			
Baseball	62 (4.6)	1 (0.5)	
Basketball	192 (14.4)	17 (8.5)	
Broomball		1 (0.5)	
Cheer	32 (2.4)	10 (5.0)	
Cross-country or track	50 (3.7)	1 (0.5)	
Dance		2 (1.0)	
Field hockey	3 (2.0)	1 (0.5)	
Figure skating		1 (0.5)	
Football	245 (18.4)	96 (48.0)	
Golf	16 (1.2)		
Gymnastics	44 (3.3)	1 (0.5)	
Ice hockey	30 (2.2)	1 (0.5)	
Lacrosse	39 (2.9)	7 (3.5)	
Quidditch		2 (1.0)	
Rowing	35 (2.6)	5 (2.5)	
Rugby	7 (0.5)	2 (1.0)	
Soccer	268 (20.1)	23 (11.5)	
Softball	44 (3.3)	7 (3.5)	
Swimming and diving	68 (5.1)	5 (2.5)	
Tennis	33 (2.5)		
Ultimate frisbee		2 (1.0)	
Volleyball	71 (5.3)	5 (2.5)	
Wrestling	95 (7.1)	10 (5.0)	
Age	16.75 ± 2.28	17.37 ± 2.45	>.001

[a] $P < .05$.

Procedures

We obtained university institutional review board approval and parental informed consent and minor assent or informed consent for each adult participant. The SCAT symptom inventory was administered by a trained researcher or certified athletic trainer in a quiet environment at each institution's designated testing area (eg, classroom or research laboratory) for both the healthy, uninjured and acutely concussed high school and collegiate athletes.

Data Analysis

Descriptive statistics, including frequency, mean, standard deviation, skewness, and kurtosis, were calculated for both samples. An independent *t* test and χ^2 analyses were conducted to ensure sample equivalence. We performed separate exploratory factor analyses (EFAs) using a principal component analysis and varimax extraction method on the 22 symptoms for the 2 groups. Before conducting the separate EFAs, we evaluated the data suitability. Inspection of the correlation matrices revealed that most of the coefficients were above 0.3, suggesting suitability for factor analysis.[20] Kasier-Meyer-Olkin (KMO) values met the recommended value (0.6), and the Barlett test of sphericity reached statistical significance ($P \leq .001$).[20] Finally, all included factors had eigenvalues greater than 1.0, and a scree plot was used to further identify the number of factors included before the breaking point, or elbow. As per the previous EFA,[7] items were included in the factor if the primary factor loading was $\geq$0.50. Items that cross-loaded (>0.40) on 2 or more factors were included only when the main loading was $\geq$0.60 and the difference between the main and highest cross-loading was $\geq$0.20.[7] Items that did not meet the primary factor-loading criteria were excluded from the factor. Factors were named based on the symptoms that loaded onto each factor.

RESULTS

Descriptive Information for the Healthy, Uninjured Sample

The healthy, uninjured sample consisted of 1334 athletes (Table 1). The majority of participants were male (n = 694 [52.1%]; females = 637 [47.9%]) and high school athletes (906 [67.9%]; collegiate = 428 [32.1%]). Healthy, uninjured participants were 16.75 ± 28 (range = 12–24) years old. Eight percent (n = 103) did not provide their age; however, they were all current participants in high school athletics. A total of 91 (6.8%; missing = 150 [11.2%])

Table 2. Symptoms of the Healthy, Uninjured Sample (n = 1334)

Symptom	Frequency, n (%)	Mean ± SD	Skewness	Kurtosis
Fatigue or low energy	298 (22.3)	0.36 ± 0.81	2.80	9.39
Trouble falling asleep	202 (15.1)	0.31 ± 0.92	3.71	15.05
Headache	190 (14.2)	0.24 ± 0.69	3.63	15.87
Nervous or anxious	189 (14.2)	0.23 ± 0.69	4.25	23.65
Difficulty concentrating	188 (14.1)	0.24 ± 0.70	3.88	17.93
Difficulty remembering	163 (12.2)	0.20 ± 0.63	4.14	20.58
Drowsiness	150 (11.2)	0.19 ± 0.63	4.02	18.69
"Pressure in the head"	135 (10.1)	0.16 ± 0.58	4.47	23.18
Neck pain	119 (8.9)	0.16 ± 0.62	4.73	25.84
Feeling slowed down	111 (8.9)	0.14 ± 0.54	5.55	37.90
Irritability	111 (8.3)	0.15 ± 0.61	5.40	35.24
More emotional	96 (7.2)	0.13 ± 0.57	5.67	38.95
Dizziness	92 (6.9)	0.11 ± 0.45	5.07	28.78
Balance problems	87 (6.5)	0.11 ± 0.48	5.56	35.62
"Don't feel right"	84 (6.3)	0.10 ± 0.44	5.86	44.81
Sensitivity to light	72 (5.4)	0.09 ± 0.48	7.60	69.63
Sadness	63 (4.7)	0.09 ± 0.48	7.26	63.42
Blurred vision	58 (4.3)	0.07 ± 0.37	6.47	47.37
Feeling in a fog	56 (4.2)	0.06 ± 0.36	7.37	67.04
Sensitivity to noise	39 (2.9)	0.05 ± 0.39	10.02	118.03
Confusion	36 (2.7)	0.05 ± 0.35	10.38	131.15
Nausea or vomiting	35 (2.6)	0.04 ± 0.24	7.78	68.06

participants in the healthy, uninjured sample reported being diagnosed or treated for headaches or migraines; 94 (7.0%; missing = 192 [14.4%]) participants were diagnosed with a learning disability, attention-deficit/hyperactivity disorder (ADHD), or attention-deficit disorder (ADD); 49 (3.7%; missing = 175 [13.1%]) were diagnosed with depression, anxiety, or other psychiatric disorder; and 255 (19.1%) had a history of concussion. These values were similar to the population prevalences of headaches and migraines[21,22] and ADD or ADHD[23,24] in children and adults.

The frequency, mean, standard deviation, skewness, and kurtosis values for the healthy, uninjured sample appear in Table 2. Because healthy individuals reported very few symptoms, as expected, the group's symptoms were low, skewed, and kurtosed. Overall, the average total symptom severity score for the healthy sample was 3.27 ± 7.01.

Exploratory Factor Analyses for the Healthy, Uninjured Sample

The EFA for the healthy, uninjured sample yielded a 3-factor solution, which accounted for 48.1% of the total variance with a KMO value of 0.90. The 3 factors were (1) cognitive-fatigue (34.2% of the variance, eigenvalue = 7.52, 6 symptoms), (2) migraine (7.8% of the variance, eigenvalue = 1.71, 5 symptoms), and (3) affective (6.2% of the variance, eigenvalue = 1.36, 5 symptoms). Three symptoms (difficulty remembering, balance problems, and blurred vision) did not meet the primary loading criteria (>0.50) and, therefore, were excluded. Three symptoms (nausea or vomiting, dizziness, and difficulty concentrating) were excluded due to high cross-loading. The factor structure and loadings for the healthy sample are described in Table 3. Additionally, 3 more factors had eigenvalues > 1 (eigenvalues = 1.16, 1.07, and 1.04); however, we chose a 3-factor solution due to (1) the leveling of the scree plot following 3 factors and (2) an insufficient number (≤2 items) of primary loadings onto a factor.

Descriptive Information for the Acutely Concussed Sample

The acute postinjury sample consisted of 200 athletes with concussion. Most participants were male (132 [66.0%]; females = 68 [34.0%]) and high school athletes (108 [54.0%]; collegiate = 92 [46.0%]). The average age of the acute postinjury participants was 17.37 ± 2.5 (range = 13–23) years old. The postinjury symptom assessment occurred 1.79 ± 1.1 (range = 0–3) days after injury.

Table 3. Symptom Factor-Loading Structure for the Healthy, Uninjured Sample (n = 1334)

	Factor		
Symptom	Cognitive-Fatigue	Migraine	Affective
Headache	0.318	0.661[b]	0.138
"Pressure in the head"	0.421	0.632[b]	0.073
Neck pain	0.006	0.666[b]	0.139
Nausea or vomiting[a]	0.208	0.476	0.062
Dizziness[a]	0.494	0.435	0.089
Blurred vision[a]	0.296	0.367	0.245
Balance problems[a]	0.306	0.302	0.217
Sensitivity to light	0.242	0.556[b]	0.113
Sensitivity to noise	−0.011	0.584[b]	0.229
Feeling slowed down	0.684[b]	0.218	0.190
Feeling "in a fog"	0.770[b]	0.218	0.084
"Don't feel right"	0.755[b]	0.268	0.078
Difficulty concentrating[a]	0.434	0.375	0.361
Difficulty remembering[a]	0.350	0.356	0.303
Fatigue or low energy	0.599[b]	0.055	0.389
Confusion	0.662[b]	0.272	0.235
Drowsiness	0.653[b]	0.034	0.232
More emotional	0.081	0.213	0.795[b]
Irritability	0.172	0.192	0.688[b]
Sadness	0.183	−0.007	0.790[b]
Nervous or anxious	0.279	0.171	0.639[b]
Trouble falling asleep	0.157	0.264	0.532[b]

[a] Item was eliminated because it did not meet factor-loading criteria or was cross-loaded with 2 or more factors.
[b] Item met factor-loading criteria (>0.50).

Table 4. Symptoms of the Acutely Concussed Sample (n = 200)

Symptom	Frequency, n (%)	Mean ± SD	Skewness	Kurtosis
Headache	182 (91.0)	2.45 ± 1.38	−0.05	−0.83
"Pressure in the head"	175 (87.5)	2.12 ± 1.36	0.21	−0.66
Feeling slowed down	150 (75.0)	1.75 ± 1.45	0.44	−0.78
Difficulty concentrating	146 (73.0)	1.85 ± 1.63	0.58	−0.59
Fatigue or low energy	139 (69.5)	1.81 ± 1.64	0.55	−0.66
"Don't feel right"	135 (67.5)	1.70 ± 1.66	0.74	−0.40
Sensitivity to light	129 (64.5)	1.52 ± 1.49	0.68	−0.47
Drowsiness	122 (61.0)	1.41 ± 1.42	0.62	−0.71
Dizziness	118 (59.0)	1.19 ± 1.30	0.99	0.46
Feeling in a fog	116 (58.0)	1.32 ± 1.44	0.86	−0.15
Sensitivity to noise	113 (56.5)	1.26 ± 1.42	0.98	0.22
Difficulty remembering	111 (55.5)	1.15 ± 1.30	0.97	0.33
Neck pain	109 (54.5)	1.22 ± 1.44	1.03	0.07
Balance problems	93 (46.5)	0.76 ± 1.03	1.59	2.77
Confusion	83 (41.5)	0.80 ± 1.17	1.46	1.38
Irritability	82 (41.0)	1.02 ± 1.49	1.41	1.31
Nausea or vomiting	72 (36.0)	0.67 ± 1.09	1.78	2.62
More emotional	69 (34.5)	0.80 ± 1.17	1.46	1.38
Blurred vision	62 (31.0)	0.53 ± 0.96	2.08	4.32
Trouble falling asleep	60 (30.0)	0.83 ± 1.46	1.79	2.42
Nervous or anxious	58 (29.0)	0.62 ± 1.17	2.17	4.73
Sadness	50 (25.0)	0.49 ± 1.05	2.74	8.35

Seventeen (8.7%; missing = 4 [2.0%]) participants in the acute postinjury sample reported being diagnosed or treated for headaches or migraines; 14 (9.9%; missing = 59 [29.5%]) participants were diagnosed with a learning disability, ADHD, or ADD; 10 (5.1%; missing = 5 [2.5%]) were diagnosed with depression, anxiety, or other psychiatric disorder; and 73 (36.5%) had a history of concussion. The group prevalences of a history of headaches or migraines[21,22] or ADD or ADHD[23,24] were similar to population prevalences in children (<20 years) and adults.

Table 5. Symptom Factor-Loading Structure for the Acutely Concussed Sample (n = 200)

Symptom	Migraine-Fatigue	Affective	Cognitive-Ocular
Headache	0.862[b]	0.096	−0.041
"Pressure in the head"	0.775[b]	0.108	0.160
Neck pain[a]	0.318	−0.076	0.316
Nausea or vomiting[a]	0.458	0.216	0.313
Dizziness[a]	0.515	0.196	0.451
Blurred vision	0.082	0.039	0.622[b]
Balance problems	0.118	0.144	0.667[b]
Sensitivity to light	0.616[b]	0.241	0.254
Sensitivity to noise	0.674[b]	0.305	0.057
Feeling slowed down[a]	0.602	0.367	0.447
Feeling like "in a fog"[a]	0.396	0.470	0.385
"Don't feel right"	0.511[b]	0.335	0.391
Difficulty concentrating[a]	0.503	0.403	0.555
Difficulty remembering	0.057	0.060	0.725[b]
Fatigue or low energy[a]	0.496	0.412	0.446
Confusion	0.252	0.480	0.610[b]
Drowsiness[a]	0.455	0.311	0.476
More emotional	0.158	0.820[b]	0.192
Irritability	0.264	0.612[b]	0.168
Sadness	0.084	0.844[b]	0.149
Nervous or anxious	0.109	0.784[b]	0.014
Trouble falling asleep[a]	0.325	0.461	0.025

[a] Item was eliminated because it did not meet factor-loading criteria or was cross-loaded with 2 or more factors.
[b] Item met factor-loading criteria (>0.50).

The frequency, mean, standard deviation, skewness, and kurtosis values for the acute postinjury sample are outlined in Table 4. The sample's symptoms were greater than those endorsed by the healthy, uninjured sample but were also skewed and kurtosed. The average total symptom severity score for the acute postinjury sample was 26.78 ± 18.92.

Exploratory Factor Analyses for the Acutely Concussed Sample

The EFA for the acute postinjury sample revealed a 3-factor solution, which accounted for 55.0% of the variance with a KMO value of 0.89. The 3 factors were (1) migraine-fatigue (40.4% of the variance, eigenvalue = 8.89, 5 symptoms), (2) affective (7.9% of the variance, eigenvalue = 7.89, 4 symptoms), and (3) cognitive-ocular (6.72% of the variance, eigenvalue = 1.48, 4 symptoms). Three symptoms—neck pain, nausea or vomiting, and "feeling in a fog"—did not meet the primary loading criteria (>0.50) and, therefore, were excluded. Six symptoms (dizziness, feeling slowed down, difficulty concentrating, fatigue or low energy, drowsiness, and trouble falling asleep) were eliminated due to high cross-loading. The factor structure and loadings for the acute postinjury sample are described in Table 5. Two more factors had eigenvalues >1 (eigenvalues = 1.07 and 1.01); however, a 3-factor solution was chosen due to the leveling of the scree plot following 3 factors, and a 3-factor solution seemed to be more appropriate due to the lack of congruency of postinjury symptoms.

DISCUSSION

Our primary purpose was to investigate the symptom factor structure of the SCAT symptom inventory in healthy, uninjured and acutely concussed high school and collegiate athletes. Three-factor solutions were selected for both the healthy, uninjured and acute postinjury samples, with at least 4 symptoms per factor. The 3 symptom factors for the healthy, noninjured sample were cognitive-fatigue, migraine, and affective, and the 3 acute postinjury symptom factors were migraine-fatigue, affective, and cognitive-ocular. Our secondary purpose was to document the frequency of the unique items reported on the SCAT symptom inventory. Among the items unique to the SCAT symptom inventory, "pressure in the head" and neck pain were most often reported by the healthy, uninjured sample. More than half of the acute postinjury sample reported the unique SCAT symptom inventory items of "pressure in the head," "don't feel right," and neck pain.

The factors for the healthy, uninjured sample agree with those demonstrated in previous research.[9,10] Piland et al[10] identified a 3-factor structure in healthy athletes for the 16-item Graded Symptom Checklist: somatic (headache, nausea, vomiting, balance problems, sensitivity to light and noise, and numbness and tingling), neurobehavioral (sleeping more than usual, drowsiness, fatigue, sadness, nervousness, and trouble falling asleep), and cognitive (feeling "slowed down," feeling like "in a fog," difficulty concentrating, and difficulty remembering). Similar symptom factors were revealed for the Head Injury Scale in healthy athletes: somatic (headache, nausea, vomiting, balance, sensitivity to light and noise, and numbness and tingling), cognitive (feeling "slowed down," feeling like "in a fog," difficulty concentrating, and difficulty remembering), and neuropsychological (fatigue, trouble falling asleep, sleeping more than usual, drowsiness, sadness, and nervousness).[9] However, other authors[7] described a 4-factor solution for healthy athletes using the PCSS: cognitive-sensory (sensitivity to light, sensitivity to noise, feeling slowed down, mentally foggy, difficulty concentrating, difficulty remembering, and vision problems), sleep-arousal (fatigue, trouble falling asleep, sleeping less than usual, and drowsiness), vestibular-somatic (headache, nausea, vomiting, balance, and dizziness), and affective (irritability, sadness, nervousness, and feeling more emotional). Interestingly, even with the inclusion of the unique SCAT symptom inventory items, the individual symptoms loaded similarly to previous research. All of the unique SCAT symptom inventory items except for blurred vision loaded onto the healthy, uninjured symptom factors. This finding is unsurprising, given that previous investigators[25] noted common postconcussion symptoms such as fatigue, difficulty concentrating, and poor sleep among healthy, uninjured high school and collegiate athletes. In addition, somatization may increase preinjury symptom reporting.[26] However, unlike us, all previous researchers[7,9,10] who explored symptom factors in healthy athletes at baseline demonstrated a somatic symptom factor. The exclusion of numbness or tingling from the SCAT symptom inventory, as well as the combination of nausea and vomiting, may have contributed to these results.

Curiously, similar to our healthy, uninjured sample and prior exploratory factor analysis,[7] the factor that accounted for the most variance in the acute postinjury sample included fatigue-related symptoms. Previous authors[27] suggested that the neurometabolic cascade immediately after injury produces a mismatch in energy demand and energy supply in the brain. This mismatch could result in fatigue-like symptoms and may also contribute to migraine-related symptoms.[27] However, caution should be taken when comparing our healthy, uninjured and acutely concussed groups due to the differences in potential confounding factors, such as age, sex, and concussion history. In addition, "pressure in the head" was a major contributor to the migraine symptom factor in the healthy, uninjured sample and to the migraine-fatigue symptom factor in the acute postinjury sample. This finding was consistent with that of King et al,[28] who noted that 80% of participants reported "pressure in the head" within 72 hours of concussion. Health care professionals should be aware that "pressure in the head" was a major contributor to both the healthy, uninjured and acute postinjury symptom factors, which reinforces the likelihood that the clinical signs and symptoms exhibited during concussion must result from biomechanical forces and not other injuries, comorbidities, or substance use.[17]

Unlike Kontos et al,[7] we found that balance and irritability loaded onto the acute postinjury symptom factors. Previous investigators[29] indicated that balance problems were evident after concussion but diminished within 7 days of injury in more than 90% of athletes. In addition, all but 1 of the unique SCAT symptom inventory items loaded onto and were significant contributors to the acute postinjury symptom factors. For example, "pressure in the head" was the second greatest contributor to the migraine-fatigue acute symptom factor and blurred vision was the third greatest contributor to the cognitive-ocular factor. Yet neck pain did not meet the primary loading criteria and was excluded from the acute symptom factors. Interestingly, although neck pain did not meet loading factor criteria and was excluded from the analysis, over half (54.5%) of the acute postinjury participants reported neck pain within 72 hours of their concussion. This is similar to the observation by King et al[28] that 68% of individuals reported neck pain within 72 hours of injury. It is possible that neck pain does not load onto a specific symptom factor during the acute period after concussion but rather should be assessed separately after injury per consensus recommendations.[17] In addition, Kontos et al[7] described a "global" symptom factor (cognitive-migraine-fatigue) within 7 days of injury. Importantly, a "global" symptom factor was not present during the acute period when we administered the SCAT. The acute postinjury symptom factors that we identified differed from earlier work,[7] possibly because of the variation in symptom inventories used.

We aimed to understand the acute symptom factor structure of the SCAT symptom inventory, as previous researchers[1,6,7] did not discriminate between the acute and subacute periods after injury. In addition, no other authors have explored the factor structure of the SCAT, an assessment most useful immediately after injury, which contains unique items (pressure in the head, neck pain, blurred vision, "don't feel right," confusion, and combined nausea or vomiting) that may influence symptom factors. Understanding acute postinjury symptom factors may help health care professionals identify clinical profiles and prescribe appropriate treatment. For example, athletes presenting with the cognitive-ocular symptom factor may benefit more from ocular therapy than athletes with affective symptoms. Furthermore, earlier investigators[30] found that specific symptoms and symptom factors present at an initial visit were associated with longer symptom duration and greater symptom severity. Therefore, early identification of the symptom factor presentation may allow for targeted treatment that will likely influence the duration of symptoms. Future researchers should identify symptom factors early in postconcussion management to promote faster and more accurate treatment, with the ultimate goal of improving patient care.

This study was not without limitations. First, although our groups were recruited from several high schools and universities, participants were from only 2 states, which may restrict the generalizability. Second, given that the SCAT is most clinically useful in the acute period after concussion, we studied participants assessed within 72 hours of injury; therefore, our results cannot be generalized to the subacute or chronic periods after concussion. Third, health care professionals used their discretion when diagnosing the patients with concussions included in the study. Fourth, the percentage of participants with a relevant past medical history (eg, migraine; learning disability, ADD, or ADHD; anxiety; or depression) may have been underestimated due to missing information, which might have influenced the results. However, these values were similar to previously reported prevalence rates in children and adults. In addition, a history of motion sickness is not included in the SCAT demographics section, and we do not know which of our participants had this condition.

Future researchers should examine how individuals with premorbid concussion risk factors (eg, migraine history, ADHD, depression) fit into symptom factors after injury. Also, identifying successful treatment strategies for athletes with the identified symptom factors will help to improve patient care. To provide individualized care to every athlete with a diagnosed concussion, health care professionals should use these findings to guide their management and treatment decisions.

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