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Original Research

Quality of Life Differences in Children and Adolescents With 0, 1 to 2, or 3+ Persistent Postconcussion Symptoms

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Context: Persistent postconcussion symptoms (PPCSs) are associated with lower health-related quality of life (HRQoL) in children and adolescents. Despite commonly cited criteria for PPCSs involving 3 or more complaints, many individuals experience just 1 or 2 symptoms that may still negatively affect HRQoL.

Objective: To determine differences in HRQoL between children and adolescents with 0, 1 to 2, or 3+ parent-reported persistent symptoms at 1 month postconcussion.

Design: Prospective cohort study.

Setting: Community practice clinics.

Patients or Other Participants: Individuals aged 8 to 18 years presented for the initial visit within 3 days of a sport- or recreation-related concussion. One month later, parents or guardians reported persistent symptoms using the Rivermead Post Concussion Symptoms Questionnaire (RPQ). Individuals with complete symptom data were analyzed (n = 236/245, n = 97 females, age = 14.3 ± 2.1 years). Participants were grouped by the number of discrete RPQ symptoms reported as worse than preinjury (0, 1–2, or 3+).

Main Outcome Measure(s): Total summary and subscale scores on the Pediatric Quality of Life Inventory (PedsQL) 23-item HRQoL inventory and 18-item Multidimensional Fatigue Scale (MDFS).

Results: Kruskal-Wallis rank sum tests highlighted differences in PedsQL HRQoL and MDFS total scores across symptom groups (PedsQL HRQoL: $\chi^2_2 = 85.53$, $P < .001$; MDFS: $\chi^2_2 = 93.15$, $P < .001$). Dunn post hoc analyses indicated all 3 groups were statistically significantly different from each other ($P < .001$). The median (interquartile range) values for the Peds QL Inventory HRQoL totals were 93.5 (84.2–98.8) for those with 0 symptoms; 84.8 (73.9–92.4) for those with 1 to 2 symptoms; and 70.7 (58.7–78.0) for those with 3+ symptoms. The median (interquartile range) values for the MDFS totals were 92.4 (76.4–98.6) for those with 0 symptoms; 78.5 (65.6–88.9) for those with 1 to 2 symptoms; and 54.2 (46.2–65.3) for those with 3+ symptoms. Similar group differences were observed for each PedsQL HRQoL and MDFS subscale score.

Conclusions: Children and adolescents whose parents reported 1 to 2 PPCSs had lower HRQoL and more fatigue than those with 0 symptoms. Across all 3 groups, those with 3+ persistent symptoms had the lowest HRQoL and most fatigue. These findings indicate the continued need for intervention in this age group to prevent and address PPCSs.

Key Words: mild traumatic brain injury, persistent symptoms, youth, sport-related concussion, health-related quality of life

Key Points

- Children and adolescents with 1 to 2 persistent postconcussion symptoms reported a lower health-related quality of life and more fatigue than those with no symptoms.
- Those with 3+ persistent symptoms had the lowest health-related quality of life and the most fatigue.

Between 1.1 and 1.9 million youth sport- or recreation-related concussions occur in the United States each year.[1] Although most children and adolescents will recover from these injuries within a few weeks (median time to symptom resolution = 13 days [95% CI = 11, 15]),[2,3] a considerable portion experience prolonged symptoms that can affect their daily functioning and delay the return to sport or school.[4–6] Criteria for *persistent symptoms* vary, but one of the most common definitions involves endorsing ≥3 symptoms as worse than before the injury at least 1 month after concussion.[7–11]

Compelling evidence suggests that persistent postconcussion symptoms (PPCSs) are associated with lower health-related quality of life (HRQoL) in children and adolescents. Novak et al[11] measured children's HRQoL using the Pediatric Quality of Life Inventory (PedsQL) at 4, 8, and 12 weeks after concussion. Patients meeting the criteria for PPCSs (n = 510/1667; 31%) had statistically significantly lower physical, emotional,

social, and school PedsQL subscale scores and lower HRQoL than published healthy norms at all 3 timepoints than did those without persistent symptoms. Clinically meaningful impairments in school-related functioning and worse quality of life (QoL) over time have also been observed in adolescents with prolonged concussion symptoms (ie, individuals whose physicians documented > 28 days to reach full clinical recovery).[12] Qualitative results augmented these findings, with many adolescent athletes and their parents expressing that the physical symptoms of their concussion substantially affected their emotional and academic functioning throughout recovery.[13]

Despite commonly cited criteria for persistent symptoms involving ≥3 complaints, many patients experience just 1 or 2 symptoms that may still affect their daily functioning, thereby delaying a full recovery.[14] Athletes with lingering symptoms may not meet the diagnostic criteria for PPCSs and yet experience decrements in QoL, including feelings of worry or despair surrounding their injury's effect on their return to sport or school.[15] Hearps et al[14] suggested that some diagnostic criteria may be overly specific in assessing the effect of PPCSs. Compared with common cutoff scores involving 3+ items being rated as worse than preinjury, Hearps et al[14] determined that a stricter 2+ item or 1+ increase in symptom severity score more accurately classified symptomatic children than published criteria.[14] Therefore, it is important to explore the relationship between PPCSs and HRQoL, not only in those experiencing 3 or more symptoms but also in those with just 1 or 2, as these individuals' QoL may still be affected. Understanding these relationships can help support athletic trainers' and other sports medicine health care professionals' clinical decision-making postconcussion.

Thus, the purpose of our investigation was to determine differences in HRQoL among children and adolescents with 0, 1 to 2, or 3+ PPCSs at 1 month postinjury. Based on previous research,[2] we hypothesized that those experiencing greater numbers of persistent symptoms would have lower HRQoL across multiple domains than those with fewer symptoms.

METHODS

Participants

A prospective cohort of children and adolescents aged 8 to 18 years old, all of whom experienced a sport- or recreation-related concussion (Table 1), reported to 1 of 3 community-based primary care clinics offering comprehensive sport-related concussion management services within 3 days of injury (n = 332; days between injury and clinic visit = 1.7 ± 0.8 [range = 0–3]). All injuries were diagnosed as concussions by physicians. We contacted the parents or guardians of the enrolled participants to obtain follow-up information approximately 1 month after the injury (median = 36 days; interquartile range [IQR] = 31–41 days). A total of 245 individuals participated in the follow-up timepoint, and those with complete symptom data were analyzed (n = 236/245, n = 97 females, n = 70 with a history of head injury, age = 14.3 ± 2.1 years; Table 2).

Procedures

This investigation was approved by the institutional review board at The University of North Carolina at Chapel Hill. At the initial visit, parents or guardians and patients provided informed consent or assent as appropriate, basic demographic information, and details about the injury (severity, mechanism, etc). They also provided initial symptom reports and performed cognitive and balance assessments. To ensure inclusion of only those diagnosed with concussion, we excluded patients presenting with any of the following: penetrating skull injury, focal neurologic deficit, developmental delay, preexisting neurologic disorder (eg, seizure disorder), ventricular shunt, bleeding disorder, or evidence of substance abuse. In addition, non-English speakers were excluded. Approximately 1 month later, parents or guardians of the enrolled participants were contacted via phone and asked to provide information about their children's persistent symptoms, HRQoL, fatigue, and return to activity. Parent or guardian phone reports were chosen for pragmatic purposes to maximize the likelihood of obtaining follow-up responses.

Table 1. Sports and Recreational Activities in Which Injuries Were Sustained

Sport or Recreational Activity	Participants, No.[a]		
	All (n = 236)	Males (n = 138)	Females (n = 97)
Baseball	11	11	0
Basketball	20	11	9
Biking	2	2	0
Cheerleading	15	0	15
Color guard	1	0	1
Cross-country	1	0	1
Diving	1	1	0
Dodgeball	2	2	0
Field hockey	2	0	2
Football	50	50	0
Gymnastics	3	0	3
Handball	2	2	0
Hockey	15	15	0
Horseback riding	3	0	3
Ice skating	1	0	1
Lacrosse	16	10	5
Rugby	1	1	0
Skiing	1	1	0
Soccer	61	21	40
Softball	1	0	1
Swimming	1	0	1
Tennis	2	1	1
Trampoline	2	1	1
Volleyball	12	0	12
Wakeboard	1	1	0
Water tubing	1	0	1
Wrestling	8	8	0

[a] One participant did not report sex.

Measures

Persistent Postconcussion Symptoms. We used the Rivermead Post Concussion Symptoms Questionnaire (RPQ) to assess PPCSs.[16] This measure is valid and reliable and has been used by previous researchers[3,17–21] to evaluate PPCSs, including those based on parents' reports. Parents or guardians identified the severity of their children's concussion symptoms (18 items total) over the course of the past week as compared with before the head injury, using a scale of 0 to 4 (0 = *not experienced at all*, 1 = *no more of a problem now than before the accident*, 2 = *a mild problem now*, 3 = *a moderate problem now*, or 4 = *a severe problem now*). A symptom was considered *persistent* if it was rated as ≥ 2,

Table 2. Participant Demographic, Symptom, Health-Related Quality of Life, and Multidimensional Fatigue Scale Information

Measure	All Participants (N = 236) No. (%) or Mean ± SD [Range]
Demographics	
Age, y	14.3 ± 2.1 [8.0–18.0]
Female sex	97 (41.1)
Race	
African American	18 (7.6)
Asian	2 (0.9)
White	177 (75.0)
Other	3 (1.3)
No race listed	40 (17.0)
History of head injury	70 (29.7)
History of anxiety	27 (11.4)
History of depression	6 (2.5)
Initial symptoms[a]	
No. of initial symptoms endorsed	10.2 ± 5.5 [0.0–24.0]
Initial symptom severity score	27.5 ± 20.1 [0.0–112.0]
Persistent symptoms[b]	
No. of persistent symptoms endorsed	2.2 ± 3.7 [0.0–16.0]
Persistent symptom severity score	8.3 ± 10.2 [0.0–46.0]
Pediatric Quality of Life Inventory score	Median (Interquartile Range) [Range]
Health-related quality of life score	
Summary	
Total	87.0 (72.8–95.7) [34.8–100.0]
Psychosocial	86.7 (72.5–95.8) [33.3–100.0]
Subscale	
Physical	87.5 (71.9–100.0) [15.6–100.0]
Emotional	90.0 (75.0–100.0) [10.0–100.0]
Social	100.0 (90.0–100.0) [50.0–100.0]
School	75.0 (60.0–95.0) [0.0–100.0]
Multidimensional Fatigue Scale score	
Total	80.0 (59.7–95.8) [20.8–100.0]
Subscale	
General fatigue	79.2 (62.5–95.8) [8.3–100.0]
Sleep fatigue	79.2 (58.3–95.8) [4.2–100.0]
Cognitive fatigue	83.3 (58.3–100.0) [0.0–100.0]

[a] 26 total items, each rated on a scale of 0–6.
[b] 18 total items, each rated on a scale of 0–4.

indicating that it was more of a problem at the 1-month follow-up timepoint than it had been preinjury. Responses to each item were summed to create a composite severity score with a possible range of 0 to 72.

Health-Related Quality of Life. The 23-item PedsQL (version 4.0) was administered to measure HRQoL. Parents or guardians were presented with a list of items in 4 categories (physical [8 items], emotional [5 items], social [5 items], and school functioning [5 items]) and asked to select how much of a problem each one had been for their child during the past month. Response options range from 0 to 4 (0 = *never a problem*, 1 = *almost never a problem*, 2 = *sometimes a problem*, 3 = *often a problem*, or 4 = *almost always a problem*). This measure is reliable and valid as a parental report,[22] has been used in clinical samples of children and adolescents including those with brain injury,[23–25] and can be obtained via phone.[26] For ease of interpretability, items on the PedsQL are reverse scored and linearly transformed on a 0 to 100 scale (ie, 0 = 100, 1 = 75, 2 = 50, 3 = 25, and 4 = 0) such that higher scores indicate better HRQoL. Outcome variables for the PedsQL HRQoL are the total summary score (including all 4 subscales), psychosocial health summary score (emotional, social, and school subscales) and each subscale score (physical, emotional, social, and school).

Multidimensional Fatigue. Multidimensional fatigue was measured using the 18-item PedsQL Multidimensional Fatigue Scale (MDFS; standard version). Parents or guardians were again presented with a list of tasks that might be a problem for their child and asked to describe how much of a problem each one had been for their child during the past month. The PedsQL MDFS was designed to be used as both a child self-report and parent proxy-report measure of fatigue in pediatric patients and has demonstrated excellent reliability, validity, and parent-child agreement in clinical samples, including those with mild traumatic brain injury.[27–32] Response options range from 0 to 4 (0 = *never a problem*, 1 = *almost never a problem*, 2 = *sometimes a problem*, 3 = *often a problem*, or 4 = *almost always a problem*). Subscale categories are general (6 items), sleep or rest (6 items), and cognitive (6 items) fatigue. Items on the MDFS are reverse scored and linearly transformed on a 0 to 100 scale (ie, 0 = 100, 1 = 75, 2 = 50, 3 = 25, and 4 = 0) such that higher scores indicate a higher level of functioning within each domain. Outcome variables for the MDFS are the total summary score (comprising all subscales) and each subscale score (general, sleep, and cognitive).

Statistical Analysis

All variables and analysis residuals were screened for homogeneity of variance and normality using residual plots, Levene tests, Q-Q plots, and Shapiro-Wilk tests. Due to the nonnormal distribution of the outcome variables (Shapiro-Wilk P values $< .001$), we calculated nonparametric Kruskal-Wallis rank sum tests to compare differences in HRQoL and multidimensional fatigue among the symptom groups. Dunn post hoc analyses controlling for multiple comparisons and adjusted with the Holm method were then conducted to further examine significant omnibus results. All analyses were performed in R (version 4.2.2; The R Foundation)[33] using an α level of .05. Given a sample size of 236 participants, 3 comparison groups, and a β of 0.20 (ie, 80% power), our study theoretically had sufficient sensitivity to detect group differences in HRQoL if they exceeded an effect size of approximately 0.20, as computed using G*Power (version 3.1; Heinrich-Heine Universität Dusseldorf).[34]

RESULTS

Descriptive Statistics

A total of 136 individuals (57.6%) had 0 parent-reported PPCSs, and 38 individuals (16.1%) had 1 or 2. Sixty-two individuals (n = 62/236; 26.2%) met the criteria for PPCSs based on their parents' reports (ie, experiencing $\geq$ 3 symptoms at levels greater than before the initial injury at the 1-month timepoint). In the overall sample, parents endorsed 2.2 ± 3.7 symptoms as worse than before the injury (range = 0–16), and the total severity score on the RPQ was 8.3 ± 10.2 (range = 0–46). See Table 2 for complete descriptive statistics for the demographic factors, persistent symptoms, and PedsQL and

Table 3. Symptom Report Frequencies and Proportions in Those Rating 1–2 or 3+ Symptoms as Worse Than Preinjury at 1-Mo Follow-Up

	Symptom Group, No. (%)	
Symptom	1–2 (n = 38)	3+ (n = 62)
Headaches	16 (42.1)	44 (71.0)
Fatigue	11 (28.9)	40 (64.5)
Frustrated	3 (7.9)	38 (61.3)
Irritability	3 (7.9)	37 (59.7)
Taking longer to think	1 (2.6)	33 (53.2)
Poor concentration	1 (2.6)	33 (53.2)
Forgetful	3 (7.9)	30 (48.4)
Reduced tolerance to emotional stress	0 (0)	28 (45.2)
Noise sensitivity	1 (2.6)	28 (45.2)
Dizziness	4 (10.5)	27 (43.5)
Light sensitivity	2 (5.3)	27 (43.5)
Sleep disturbance	2 (5.3)	23 (37.1)
Fear of permanent symptoms	4 (10.5)	17 (27.4)
Restlessness	0 (0)	17 (27.4)
Depression	0 (0)	16 (25.8)
Blurred vision	0 (0)	13 (21.0)
Nausea or vomiting	0 (0)	7 (11.3)
Double vision	1 (2.6)	6 (9.7)

MDFS scores. See Table 3 for individual RPQ symptom item report frequencies and proportions in the 1 to 2 and 3+ symptom groups.

Group Differences in HRQOL

Differences were present across symptom groups for the PedsQL total score ($\chi^2_2 = 85.53$, $P < .001$). Post hoc analyses indicated that all 3 groups were significantly different from each other ($P < .001$) with median (IQR) values of 93.5 (84.2–98.8) for those with 0 symptoms; 84.8 (73.9–92.4) for those with 1 to 2 symptoms; and 70.7 (58.7–78.0) for those with 3+ symptoms. Statistically significant group differences were also observed for the psychosocial health summary score ($\chi^2_2 = 79.76$, $P < .001$). The post hoc analyses again demonstrated that all 3 groups were different from each other ($P < .001$) with median (IQR) values of 93.3 (83.3–100.0) for those with 0 symptoms); 85.0 (73.8–92.9) for those with 1 to 2 symptoms; and 69.2 (58.3–79.6) for those with 3+ symptoms. The same pattern was noted for the physical, emotional, and school subscale scores; all 3 symptom groups statistically significant differed from one another, with the lowest HRQoL seen in those with 3+ PPCSs (see Table 4 for medians and IQRs, Kruskal-Wallis rank sum test results, and nonparametric effect size estimates). For the social subscale score, those with 0 and 1 to 2 PPCSs did not differ from each other, but both groups had higher scores than did those with 3+ symptoms. Box plots of each HRQoL subscale score, separated across symptom groups, are available in Figure 1.

Group Differences on the MDFS

Significant differences were evident across symptom groups for the MDFS total score ($\chi^2_2 = 93.15$, $P < .001$). Post hoc analyses indicated that all 3 groups were significantly different from each other ($P < .001$), with median (IQR) values of 92.4 (76.4–98.6) for those with 0 symptoms; 78.5 (65.6–88.9) for those with 1 to 2 symptoms); and 54.2 (46.2–65.3) for those with 3+ symptoms. The same pattern was observed for the general, sleep, and cognitive subscale scores; all 3 symptom groups significantly differed from one another, with the lowest HRQoL observed in those with 3+ persistent symptoms

Table 4. Rivermead Post-Concussion Symptoms Questionnaire, Pediatric Quality of Life Inventory, and Multidimensional Fatigue Scale Scores

	Symptom Group, Median (Interquartile Range)			Kruskal-Wallis Rank Sum Test		Nonparametric
Score	0 (n = 136)	1–2 (n = 38)	3+ (n = 62)	χ^2_2	*P* Value	Effect Size (η^2)
Rivermead Post Concussion Symptoms Questionnaire total symptom severity	1.0 (0.0–4.0)	6.5 (4.0–8.8)	19.0 (14.0–28.8)	149.99	<.001	0.635
Pediatric Quality of Life Inventory health-related quality of life						
Summary						
Total	93.5 (84.2–98.8)	84.8 (73.9–92.4)	70.7 (58.7–78.0)	85.53	<.001	0.358
Psychosocial	93.3 (83.3–100.0)	85.0 (73.8–92.9)	69.2 (58.3–79.6)	79.76	<.001	0.334
Subscale						
Physical	96.9 (87.5–100.0)	81.3 (72.7–90.6)	71.9 (54.7–81.3)	70.35	<.001	0.293
Emotional	95.0 (87.5–100.0)	85.0 (75.0–95.0)	70.0 (55.0–80.0)	80.92	<.001	0.339
Social	100.0[a] (95.0–100.0)	100.0[a] (95.0–100.0)	90.0 (70.0–100.0)	28.96	<.001	0.116
School	85.0 (70.0–100.0)	77.5 (61.3–90.0)	50.0 (40.0–65.0)	60.07	<.001	0.249
Multidimensional Fatigue Scale						
Total	92.4 (76.4–98.6)	78.5 (65.6–88.9)	54.2 (46.2–65.3)	93.15	<.001	0.391
Fatigue subscale						
General	91.7 (79.2–100.0)	75.0 (63.5–91.7)	58.3 (41.7–66.7)	90.53	<.001	0.380
Sleep	91.7 (75.0–100.0)	75.0 (62.5–87.5)	54.6 (45.8–66.7)	75.55	<.001	0.316
Cognitive	95.8 (75.0–100.0)	79.2 (63.5–100.0)	50.0 (37.5–75.0)	75.15	<.001	0.314

[a] All medians except those sharing superscripts differed at $\alpha = .01$, as determined via Dunn post hoc tests controlling for multiple comparisons and adjusted with the Holm method. Persistent postconcussion symptom groups indicate the number of items endorsed as worse than preinjury at the 1-mo timepoint. The η^2 effect size estimates a range from 0 to 1 and, when multiplied by 100, indicates the percentage of variance in the dependent variable explained by the independent variable.

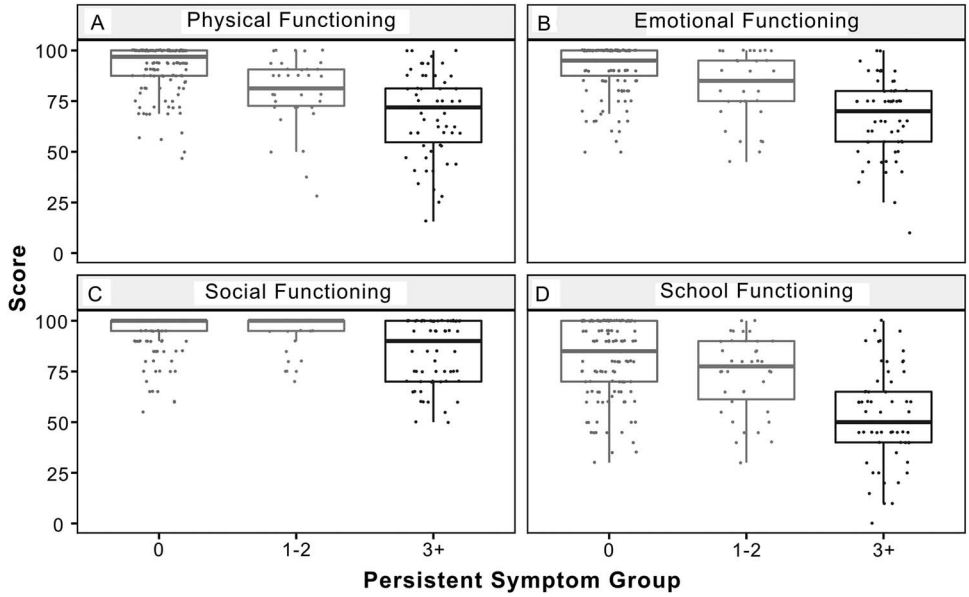

Figure 1. Box plots showing medians and interquartile ranges for health-related quality of life scores on each subscale of the Pediatric Quality of Life Inventory: A, physical functioning, B, emotional functioning, C, social functioning, and D, school functioning.

(Table 4 provides medians and IQRs, Kruskal-Wallis rank sum test results, and nonparametric effect size estimates). Box plots of each MDFS subscale score, separated across symptom groups, are supplied in Figure 2.

DISCUSSION

Our aim was to determine differences in HRQoL and multidimensional fatigue 1 month after sport- or recreation-related head injury in children and adolescents with 0, 1 to 2, or 3+ PPCSs. Consistent with the current literature,[11,12] our findings indicated that those meeting commonly cited criteria for PPCSs had deficits in HRQoL. Novel results were the differences across those with 0, 1 to 2, or 3+ persistent symptoms.

Compared with normative data in adolescent athletes,[35] those with 0 PPCSs mirrored typical HRQoL values in the total and subscale scores. However, for almost every subscale of HRQoL and MDFS, children and adolescents whose parents reported 1 to 2 PPCSs had lower QoL and more fatigue than those with none. In addition, across all 3 groups, those whose parents reported 3+ persistent symptoms had the lowest HRQoL—approximately 20 points (2 SDs) lower than the normative PedsQL total, physical, emotional, and school scores in adolescent athletes[35]—and the most fatigue.

These results build upon existing work examining children and adolescents who met the criteria for PPCSs, adding nuance regarding those with just 1 or 2 lingering symptoms. Consistent with evidence from Hearps et al,[14] even individuals with < 3 PPCSs may warrant additional clinical examination or

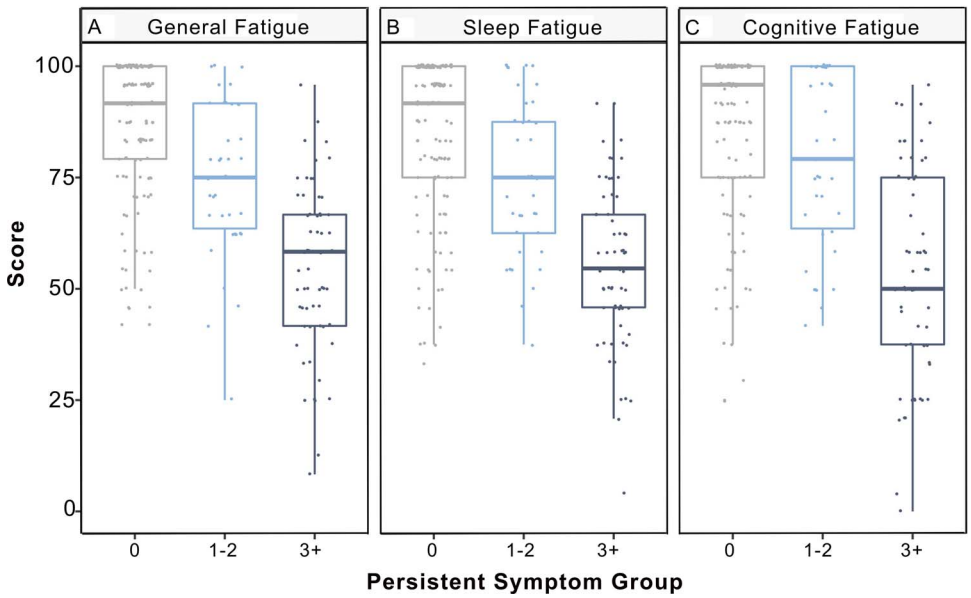

Figure 2. Box plots showing medians and interquartile ranges for scores on each subscale of the Multidimensional Fatigue Scale: A, general fatigue, B, sleep fatigue, and C, cognitive fatigue.

intervention. The findings related to QoL and fatigue supplement those of previous studies, both quantitatively and qualitatively. Novak et al[11] demonstrated that school functioning PedsQL scores were lower for children with concussions (regardless of PPCS status) at 4, 8, and 12 weeks postinjury than for healthy individuals. Complementary evidence from Lam et al[35] showed a strong association between recovery length and school functioning: those who took longer to recover had lower HRQoL related to school. Qualitative evidence from Iadevaia et al[13] addressed adolescent athletes' and parents' reports of physical concussion symptoms affecting emotional and academic function. Taken together, these findings suggest a possibly unique relationship between concussion symptoms and school functioning that warrants further exploration. Indeed, individuals in our sample with 1 to 2 or 3+ PPCSs displayed considerably lower levels of school functioning than those with none (median [IQR] values = 85.0 [70.0–100.0] for those with 0 symptoms, 77.5 [61.3–90.0] for those with 1 to 2 symptoms, and 50.0 [40.0–65.0] for those with 3+ symptoms). These values were also lower than normative data from adolescent athletes, whose average school functioning values on the PedsQL were around 84.[35] The driving mechanism behind these group differences is unclear, but 1 potential factor that could be underpinning these school-related challenges is postconcussion fatigue.

Our participants whose parents reported 3+ PPCSs at 1 month postinjury had the highest (ie, worst) levels of general, sleep, and cognitive fatigue. Interestingly, even those with just 1 or 2 symptoms reported more fatigue across all 3 subscales of the MDFS than those with 0 symptoms. Fatigue is among the most common symptoms of concussion and one that has great potential to specifically interfere with return to school, given the nature and demands of a classroom setting.[36] Children, adolescents, and parents all report worsening of fatigue during concussion recovery—with adolescents especially highlighting cognitive fatigue and its effect on schoolwork.[37] In some individuals, postconcussion fatigue may linger for months or even years,[36] so identifying targets for early intervention is especially relevant in the context of fatigue-related HRQoL deficits.

Notably, individuals in all 3 symptom groups scored highly on the social functioning subscale (median [IQR] = 100.0 [95.0–100.0] for those with 0 symptoms; 100.0 [95.0–100.0] for those with 1–2 symptoms; and 90.0 [70.0–100.0] for those with 3+ symptoms), suggesting that this aspect of HRQoL may not be as strongly associated with PPCSs as the other domains. Nonetheless, because the scores were parent reported and most children spend several hours per day away from their parents while at school, it is certainly possible that the parents may have lacked a full picture of their children's level of social functioning postconcussion. Regardless, this result also supports future investigators' examinations of nuance in HRQoL group differences using both overall summary and subscale scores.

A few limitations of our study must be considered. First, HRQoL was measured at a single timepoint via parent or guardian report at 1 month after injury. We did not measure HRQoL at the initial visit timepoint and, therefore, were unable to evaluate change scores or to use HRQoL scores as predictors of prolonged recovery. Attrition was another concern, as we were unable to contact several families at 1 month who participated in the initial visit.

Interestingly, a bidirectional relationship between HRQoL and postconcussion symptoms may prove useful in the development of early, targeted interventions to identify those at risk of prolonged recovery and may inform clinicians' decision-making. To illustrate, initial and longitudinal HRQoL outcomes were compared between adolescents aged 13 to 18 years who did or did not develop *postconcussion syndrome* (in this case, defined as the presence of ≥ 3 symptoms at 30 days postinjury). Patients who went on to develop postconcussion syndrome had worse physical and cognitive HRQoL at the initial postinjury timepoint and demonstrated a slower rate of recovery in these domains than those who recovered in < 30 days.[38] (Although many previous authors have used definitions or criteria incorporating *postconcussion syndrome*, evolutions in terminology indicate that *persistent postconcussion symptoms* is preferable for both researchers and clinicians, as it may help to create a more positive, action-based framework after injury and foster expectations of recovery.) Also, adolescents with a prolonged recovery (ie, >30 days) exhibited lower HRQoL immediately after injury, particularly in the domains of physical and school functioning, fatigue, and headache. Future researchers should collect measures of HRQoL and fatigue in individuals with 1 to 2 and 3+ symptoms across multiple timepoints to track the trajectory of HRQoL changes. Future investigators should also explore the role of factors such as concussion history and the burden of previous concussions in the relationship between persistent symptoms and HRQoL.

Second, we relied on parent versus child self-reports of persistent symptoms, HRQoL, and fatigue. Of note, because parents are the primary drivers of care-seeking for their children after concussion, their perception of their children's HRQoL is likely related to care-seeking decisions. Despite moderate-to-strong agreement between child and parent reports of concussion symptoms, discrepancies in individual symptom reports—especially those cognitive in nature—often exist.[39] Interestingly, comparisons of self-reported versus parent-reported fatigue on the MDFS after concussion have highlighted that, even though these reports tend to be very similar, a few differences should be acknowledged.[37] For general and sleep fatigue, self-reports and parent reports were not statistically significantly different from one another; however, for cognitive fatigue, self-reports were worse than parent reports.[37] Especially for adolescents compared with children, these cognitive fatigue deficits appeared to manifest in schoolwork and other cognitively demanding activities. It is important then to consider both self-reports and parent or guardian reports when assessing HRQoL, especially in the domain of cognitive fatigue. In our sample, the most often reported persistent symptoms by parents in both the 1 to 2 and 3+ symptom groups were headache and fatigue, and more than half of individuals in the 3+ group had parent-reported difficulties with taking longer to think and poor concentration (see Table 3). These results are particularly concerning in light of findings that compared with matched control participants, concussed adolescents demonstrated deficits on objective measures of cognitive function (eg, reaction time, switch cost, reaction time variability), higher self-reported fatigue scores, and cortical activation patterns indicating compromised information processing that may underpin prolonged fatigue.[40,41]

Recent randomized controlled trials have underscored the effectiveness of active rehabilitation strategies in concussion recovery.[42] For children and adolescents predisposed to

prolonged symptoms, these practices may show a particular benefit.[43,44] Regardless of PPCS status, many individuals will experience aerobic deconditioning within 1 to 2 weeks of inactivity after a concussive injury, and this can often manifest similarly to persistent symptoms such as fatigue, irritability, and difficulty sleeping.[15] Our results emphasize that, even if individuals experience just 1 or 2 of these symptoms, HRQoL can be affected. Thus, implementation of active rehabilitation strategies targeting these challenges (eg, progressive aerobic physical activity, vestibular or visual therapies) would be beneficial to patients experiencing any number of symptoms, not only those traditionally classified as having PPCSs.

Our findings that those with 1 to 2 or 3+ PPCSs had lower HRQoL scores overall and on the physical, emotional, and school subscales than those with 0 symptoms provide perspective on objective versus subjective aspects of concussion recovery. Specifically, rather than focusing primarily on the raw number or severity of symptoms after concussion, perhaps the most important element for both patients and health care professionals to consider are the effects of these symptoms on daily function and QoL. In future work, researchers can leverage this information to examine additional aspects of QoL that may be influenced by persisting difficulties after injury.

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DISCLOSURES

Josh Bloom, MD, Janna Fonseca, ATC, and Kristen Ramsey, ATC, were employed at the study setting during the time of data collection. Valerie J. De Maio, MD, MSc, is employed by 410 Medical Inc for unrelated work. Johna K. Register-Mihalik, PhD, ATC, reports grants from the National Football League, Department of Defense, National Athletic Trainers' Association Foundation, and Centers for Disease Control and Prevention outside the submitted work and is a member of USA Football's Football Development Council. Additionally, a family member of Dr Register-Mihalik, the principal investigator on this study, has received funding to her institution from the National Operating Committee on Standard for Athletic Equipment (NOCSAE) for work that is not part of this current study. Her spouse has received a grant review panel stipend from NOCSAE unrelated to the current work. This study was funded in part by NOCSAE.

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