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CLINICAL STUDIES

Presence of Persistent Parent Reported Emotional and Behavioral-Related Concussion Symptoms Is Associated with Lower Health-Related Quality of Life in Adolescent Athletes

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Abstract

Persistent concussion symptoms in adolescents are associated with lower health-related quality of life (HRQOL). The association between persistent emotional and behavioral-related concussion symptoms (EBS) and HRQOL is unknown, however. This study was a prospective cohort of adolescent athletes presenting to a concussion clinic within three days post-concussion and completing a one-month follow-up. The independent variable in these analyses was parent reported EBS symptom presence grouped as: (1) no EBS; (2) EBS present at pre-concussion levels; and (3) EBS worse than pre-concussion. The EBS included the following concussion symptoms: feeling irritable, depressed, frustrated/impatient, restless, reduced tolerance to stress/emotion, poor concentration, and fear of permanent symptoms. Dependent variables were parent reported psychosocial, physical, and total HRQOL. Separate multi-variable linear regression models controlling for age, sex, and concussion history were used to assess the association between EBS and HRQOL. Estimated adjusted mean differences (MD) and 95% confidence intervals (CI) were used to assess associations; MDs with a 95%CI excluding 0.0 were considered statistically significant. Overall, $n = 245$ presented to the study clinic three days post-concussion and completed the one-month follow-up ($M_{age} = 14.28 \pm 2.09$ years, 59.02% male, 90.64% Caucasian, 31.84% with concussion history). At one-month post-concussion, adolescents with pre-concussion EBS levels had significantly lower psychosocial, physical, and total HRQOL than those with no EBS. In addition, those with EBS worse than pre-concussion had significantly lower psychosocial, physical, and total HRQOL than those with no EBS and EBS at pre-concussion levels. These findings highlight the importance of HRQOL assessments and that targeted interventions may be needed for those with EBS at one-month post-concussion to improve HRQOL.

Keywords: clinical measures; mild traumatic brain injury; pediatric concussion

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Introduction

Between one and two million youth and adolescents in the United States incur a sport- or recreation-related concussion (SRC) each year.¹ Concussion results in physical impairments (headache, nausea, balance) and psychological changes (increased irritability, anxiety, depression), all of which greatly impact an individual's health-related quality of life (HRQOL).²⁻⁴ After a SRC, adolescent athletes experience increased concussion symptoms, lower academic performance, and a longer recovery compared with adult athletes.^{5,6}

In adolescents, prolonged SRC recovery and the presence of overall persistent concussion symptoms (defined as symptom expression beyond the typical recovery timeframe of four weeks for youth and adolescents, commonly measured via the Rivermead Post-Concussion Symptoms Questionnaire [RPQ])² is associated with lower HRQOL.^{7,8} Specifically, at 30 days post-concussion, adolescents demonstrate an association between increased concussion symptom severity and lower physical and psychosocial HRQOL measured via the Pediatric Quality of Life Inventory (PedsQLTM).⁹

Persistent concussion symptoms are also associated with continued psychological deficits^{10,11} that cause those impacted to miss school,¹² sport,¹³ and have less societal engagement¹⁴—all of which present an added physical and mental burden to athletes, leading to long-term decreased HRQOL.

Emotional and behavioral concussion-related symptoms (EBS) such as irritability, depression, anxiety, and frustration are identified as clinical domains that may present after an individual incurs a concussion.² Previous research also identifies pre-injury history of mental health problems, specifically anxiety and depression, as potential predictors for a longer recovery by experiencing persistent concussion symptoms.¹⁵⁻¹⁷ As such, to improve overall concussion outcomes, it is crucial to understand the association between EBS at baseline and post-injury levels and HRQOL.

Despite the evidence connecting psychological deficits, symptom severity, and HRQOL, the association between specific domains of persistent concussion symptoms (i.e., somatic, cognitive, and emotional/behavioral) and HRQOL is largely unknown. This information is essential to inform impactful interventions. Therefore, this study aimed to identify the association between persistent EBS (specifically identifying those with no EBS; EBS present, but at pre-concussion levels; and EBS worse than pre-concussion) and HRQOL at one-month post-concussion in adolescent athletes.

We hypothesized that presence of both pre-concussion and post-concussion persistent EBS would be associated with decreased HRQOL at one-month post-concussion. Our analyses utilized the RPQ and PedsQLTM, common measures for concussion symptoms and HRQOL in ado-

lescents post-concussion, and controlled for concussion history, age, and sex; all of which impact HRQOL and concussion symptom reporting.¹⁸⁻²³ Understanding this association will build on current literature and provide clinicians with tools to identify patients who may require psychological-specific rehabilitation.

Methods

This study included a prospective cohort of adolescent athletes (aged 8-18) who presented to a concussion clinic within three days of a SRC and completed a one-month follow-up visit. All participants were enrolled at the initial visit. Institutional Review Board approval was obtained for the study, and all participants completed informed consent (parental consent and child assent where relevant). Inclusion criteria were: (1) aged 8-18; (2) sustained a head injury during sports activity; (3) presented to the study site within 72 h of injury; (4) minor assent and parent/legal guardian consent (where appropriate); and (5) completed the one-month study follow-up.

Patients were excluded for penetrating skull injury, focal neurologic deficits, developmental delay, pre-existing neurologic disorders (e.g., seizure disorder), ventricular shunts, bleeding disorders, evidence of substance abuse, incomplete head injury module forms, and/or incomplete one-month follow-up.

Parents/guardians and participants together reported demographic information that was completed at the initial study visit. Parents reported persistent concussion symptoms and HRQOL collected at the one-month post-SRC time point.

At the one-month follow-up visit, parent-reported persistent concussion symptoms were assessed using the RPQ, a reliable, valid questionnaire with 18 items used to assess persistent concussion symptoms in youth and adolescent populations.^{24,25} Importantly, research suggests a moderate-to-strong agreement between child and parent concussion symptom reporting.²⁶ The parent reported RPQ asked parents to rate 18 symptoms on presence and severity (scale=0-4) compared with before their child's injury.

Persistent EBS included the following symptoms on the RPQ: feeling irritable/easily angered, feeling depressed/tearful, feeling frustrated/impatient, restlessness, reduced tolerance to stress or emotional excitement, poor concentration, and fear of permanent symptoms/brain damage. Classification of EBS used in these analyses was based on the most up-to-date SRC statements released by the American Academy of Pediatrics⁵ and the Concussion in Sport Group² as well as current literature surrounding EBS.^{15,27,28} Symptoms on the RPQ are scored as follows: severity level of 0 indicating no presence; severity level of 1 indicating symptom presence at the same level as pre-concussion; and severity level of 2+ indicating that the symptom's presence is worse than before the concussion.²⁴⁻²⁶

The independent variable in these analyses included three groups consisting of those with: (1) no parent reported EBS (i.e., reported 0 for all EBS symptoms); (2) the parent reported presence of at least one EBS at pre-concussion levels (i.e., EBS same as before the concussion, at least one EBS symptom rated 1 and none rated as 2+); and (3) the parent reported presence of at least one EBS worse than pre-concussion (i.e., at least one EBS symptom rated 2+).

Parent reported HRQOL was assessed using the PedsQ Version 4.0 Parent Report, a validated, comprehensive scale used to measure HRQOL in children and adolescents. The PedsQ Version 4.0 Parent Report includes one version for ages 8–12 and another for ages 13–18. Both versions are essentially identical, containing the same number of questions, response scales, and question types but adjust verbiage to reflect developmentally appropriate verbiage. As such, in accordance with PedsQL™ guidance and current literature, the data were combined in these outcomes.^{29,30}

The PedsQL™ has been used in children and adolescents with traumatic brain injury³¹ and concussion.³ Parent proxy was utilized for feasibility and pragmatic purposes given parents make care decisions for their children in this age range. Previous work also suggests parent proxy is reliable when compared with child report³² and, thus, was used in this study.

The PedsQL™ includes questions on a 5-point scale (never to almost always) related to physical, psychosocial, emotional, social, and school functioning. These analyses utilized the psychosocial and physical health summary scores as well as the total score. Scores on the PedsQL™ range from 0–100, with higher scores closer to 100 indicating better HRQOL. To calculate scores on the 0–100 scale, responses were transposed to the following: never=100, almost never=75, sometimes=50, often=25, and almost always=0.

Using the transposed scores, the psychosocial health summary score was calculated as the mean of items in the emotional, social, and school functioning subscales (15 items); the physical health summary score was calculated as the mean of items in the physical functioning subscale (eight items); and the total score is the mean of all items (23 items). It should be noted that, because the majority of the PedsQL™ items being related to psychosocial health, there is a large overlap of items included in the psychosocial health summary score and total score. Dependent variables included the psychosocial, physical, and total scores. The HRQOL was reported at one-month post-concussion.

Descriptive statistics were computed for all variables and outcomes of interest. Means and standard deviations (SD) were computed for age, grade level in school, total EBS, and HRQOL (psychosocial, physical, and total). Frequencies and proportions were computed for sex

(female/male), race (Caucasian/non-Caucasian), concussion history (yes/no), psychological/psychiatric disorder history (yes/no), attention-deficit disorder/attention-deficit/hyperactivity disorder (ADD/ADHD) history (yes/no), and presence of EBS (yes/no).

Separate multi-variable linear regression models were used to assess the association between parent reported persistent EBS (no EBS, EBS at pre-concussion levels, and EBS worse than pre-concussion) and HRQOL at one-month post-concussion (psychosocial, physical, and total scores). All analyses controlled for concussion history, age, and sex, all of which impact HRQOL and concussion symptom reporting.^{18–23} Estimated adjusted mean differences (MD) and 95% confidence intervals (CI) were used to assess associations; MDs with 95% CI excluding 0.0 were considered statistically significant.

Results

A total of N=332 adolescents presented to the initial visit with an SRC; $n=245$ (73.80%) completed the one-month follow-up ($M_{\text{age}} = 14.28 \pm 2.09$ years, 59.02% male, 90.64% Caucasian, 31.84% with a concussion history, 7.02% with a psychological/psychiatric disorder history, and 11.84% with an ADD/ADHD history) and were included in the current study. Complete demographic information is reported in Table 1.

Table 1. Demographic Information for Adolescent Athletes

| | n | Mean ± SD |
|--------------------------------|-----|--------------|
| Age ^a | 240 | 14.28 ± 2.09 |
| | n | n (%) |
| Sex | | |
| Male | 244 | 144 (59.02) |
| Female | | 100 (40.98) |
| Race | | |
| Caucasian | 203 | 184 (90.64) |
| Non-Caucasian | | 19 (9.36) |
| Concussion history | | |
| Yes | 245 | 78 (31.84) |
| No | | 167 (68.16) |
| Psychological disorder history | | |
| Yes | 242 | 17 (7.02) |
| No | | 225 (92.98) |
| ADD/ADHD history | | |
| Yes | 245 | 29 (11.84) |
| No | | 216 (88.16) |
| Presence of EBS | | |
| Yes, worse EBS | 235 | 64 (27.23) |
| Yes, pre-concussion EBS | | 71 (30.21) |
| No | | 100 (42.55) |

SD, standard deviation; ADD, attention-deficit disorder; ADHD, attention-deficit/hyperactivity disorder; EBS, emotional behavioral-related persistent concussion symptoms.

^aAge ranged from 8–18.

Total sample percentages are based on those with reported demographic data for each variable. Missing data were as follows: age $n=5$; sex $n=1$; race $n=42$; concussion history $n=0$; psychological disorder history $n=3$; ADD/ADHD history $n=0$; and presence of EBS $n=10$.

Table 2. Means and Standard Deviations for Health-Related Quality of Life for Adolescent Athletes with No Emotional and Behavioral-Related Symptoms, Emotional and Behavioral-Related Symptoms at Pre-Concussion Levels, and Emotional and Behavioral-Related Symptoms Worse than Pre-Concussion

| | Pre-concussion EBS | | |
|---------------------------------|--------------------|---------------|---------------|
| | No EBS | Mean ± SD | Worse EBS |
| Psychosocial HRQOL ^a | 91.68 ± 10.53 | 83.27 ± 11.04 | 68.19 ± 14.21 |
| Physical HRQOL ^a | 91.74 ± 11.55 | 82.78 ± 17.57 | 70.21 ± 19.84 |
| Total HRQOL ^a | 91.69 ± 10.13 | 83.11 ± 12.21 | 69.19 ± 14.76 |

EBS, emotional behavioral-related persistent concussion symptoms; SD, = standard deviation; HRQOL, health-related quality of life.

^aPsychosocial, physical, and total HRQOL ranged from 0–100.

Overall, $n = 100$ (42.55%) adolescent athletes had no parent reported EBS, $n = 71$ (30.21%) had parent reported EBS at pre-concussion levels, and $n = 64$ (27.23%) had parent reported EBS at worse than pre-concussion (Table 1). The HRQOL MDs and SDs by groups (no EBS, EBS at pre-concussion levels, and EBS worse than pre-concussion) are reported in Table 2. Parent reported presence for each EBS symptom is outlined in Table 3.

Of those who completed the one-month follow-up, $n = 223$ provided all data needed for the primary outcomes linear regression analyses. At one-month post-concussion, the presence of parent reported persistent EBS was significantly associated with psychosocial, physical, and total HRQOL. Specifically, those with EBS at pre-concussion levels had significantly lower psychosocial (adjusted MD = -7.90, 95% CI = -11.55, -4.24), physical (adjusted MD = -8.44, 95% CI = -13.32, -3.57), and total HRQOL (adjusted MD = -8.60, 95% CI = -11.80, -4.33) compared with those with no EBS (Table 4).

Those with EBS worse than pre-concussion had significantly lower psychosocial (adjusted MD = -14.81, 95% CI = -18.84, -10.79), physical (adjusted MD = -12.59, 95% CI = -17.94, -7.23), and total HRQOL (adjusted MD = -14.04, 95% CI = -18.14, -9.93) compared with those with EBS at pre-concussion levels (Table 4). Those with EBS worse than pre-concussion had significantly lower psychosocial (adjusted MD = -22.71, 95% CI = -26.49, -18.93), physical (adjusted MD = -21.03, 95% CI = -26.07, -15.99), and total HRQOL (adjusted MD = -22.10, 95% CI = -25.96, -18.23) compared with those with no EBS (Table 4).

Discussion

This study aimed to identify the association between presence of EBS and HRQOL at one-month post-concussion in adolescent athletes. Findings indicate that the presence of persistent EBS is associated with decreased psychosocial, physical, and total HRQOL in adolescent athletes with EBS at pre-concussion levels and in those with

Table 3. Parent-Reported Presence of Individual Emotional and Behavioral-Related Concussion Symptoms in the Total Sample

| Symptom | Number who reported | n (%) |
|--|---------------------|-------------|
| Poor concentration | | |
| Presence worse than pre-concussion | | 34 (14.41) |
| Present pre-concussion | 236 | 56 (23.73) |
| No presence | | 146 (61.86) |
| Feeling depressed/tearful | | |
| Presence worse than pre-concussion | | 16 (6.81) |
| Present pre-concussion | 235 | 43 (18.30) |
| No presence | | 176 (74.89) |
| Fear of permanent symptoms/brain damage | | |
| Presence worse than pre-concussion | | 21 (8.94) |
| Present pre-concussion | 235 | 26 (11.06) |
| No presence | | 188 (80.00) |
| Feeling frustrated/impatient | | |
| Presence worse than pre-concussion | | 41 (17.37) |
| Present pre-concussion | 236 | 56 (23.73) |
| No presence | | 139 (58.90) |
| Feeling irritable/easily angered | | |
| Presence worse than pre-concussion | | 40 (17.02) |
| Present pre-concussion | 235 | 55 (23.40) |
| No presence | | 140 (59.58) |
| Restlessness | | |
| Presence worse than pre-concussion | | 17 (7.27) |
| Present pre-concussion | 234 | 22 (9.40) |
| No presence | | 195 (83.33) |
| Reduced tolerance to stress/emotional excitement | | |
| Presence worse than pre-concussion | | 28 (11.97) |
| Present pre-concussion | 234 | 44 (18.80) |
| No presence | | 162 (69.23) |

Total sample percentages are based on those with reported emotional behavioral-related persistent concussion symptoms data. Missing data were as follows: poor concentration $n = 9$; feeling depressed/tearful $n = 10$; fear of permanent symptoms/brain damage $n = 10$; feeling frustrated/impatient $n = 9$; feeling irritable/easily angered $n = 10$; restlessness $n = 11$; reduced tolerance to stress/emotional excitement $n = 11$.

No presence is symptom rated 0 on the Rivermead Postconcussion Questionnaire (RPQ), present pre-concussion is symptom rated 1 on the RPQ, and presence worse than pre-concussion is symptom rated 2+ on the RPQ.²⁴

EBS worse than before injury. Further, significantly lower scores were seen in adolescents with EBS worse than pre-concussion.

Adolescents with EBS at pre-concussion levels had significantly worse psychosocial (MD = -7.90), physical (MD = -8.44), and total HRQOL (MD = -8.06) than those with no EBS. These findings identify that those at one month who report EBS symptoms at pre-concussion levels report significantly lower HRQOL one-month post-concussion compared with those with no EBS, highlighting the importance of including pre-season mental health screening as a part of an athlete’s concussion testing. Research suggests pre-injury history of mental health problems, specifically anxiety and depression, as a potential predictor for a longer recovery by experiencing persistent concussion symptoms,^{15–17} furthering the notion that pre-injury intervention and assessment may improve post-injury outcomes.

Table 4. Adjusted Mean Differences and 95% Confidence Intervals Assessing Association of Emotional and Behavioral-Related Persistent Concussion Symptoms and Health-Related Quality of Life One Month Post-Concussion in Adolescent Athletes

| HRQOL Outcomes | Adjusted MD ^a | 95% CI |
|----------------------------------|--------------------------|-----------------|
| Psychosocial HRQOL | | |
| Pre-concussion EBS vs. no EBS | -7.90 | -11.55, -4.24* |
| Worse EBS vs. pre-concussion EBS | -14.81 | -18.84, -10.79* |
| Worse EBS vs. no EBS | -22.71 | -26.49, -18.93* |
| Physical HRQOL | | |
| Pre-concussion EBS vs. no EBS | -8.44 | -13.32, -3.57* |
| Worse EBS vs. pre-concussion EBS | -12.59 | -17.94, -7.23* |
| Worse EBS vs. no EBS | -21.03 | -26.07, -15.99* |
| Total HRQOL | | |
| Pre-concussion EBS vs. no EBS | -8.06 | -11.80, -4.33* |
| Worse EBS vs. pre-concussion EBS | -14.04 | -18.14, -9.93* |
| Worse EBS vs. no EBS | -22.10 | -25.96, -18.23* |

HRQOL, Health-related quality of life; MD, mean difference; CI, confidence interval; EBS, emotional behavioral-related persistent concussion symptoms.

*MD was statistically significant (excluded 0.00 in 95% CI).

All models utilized $n = 233$ adolescent athletes with all data needed for the primary outcomes' linear regression analyses. All models controlled for age, sex, and concussion history.

Despite this evidence, there is limited guidance for a detailed pre-season, baseline assessment for psychosocial concussion-related disturbances.⁵ It is suggested to obtain pre-existing conditions such as ADHD, depression, anxiety, and learning disabilities during the acute assessment phase⁵—a protocol that may be impacted by recall bias and may fail to capture those who have not received a formal diagnosis of a mental health disorder but nevertheless experience related symptoms.

Our data suggest that to identify those who may experience lower HRQOL post-concussion, tracking mental health symptom expression from the pre-season time point throughout the concussion recovery timeline may be beneficial. Specifically, our results indicate the need for a comprehensive baseline HRQOL measure, in addition to using that measure post-concussion and throughout recovery. Measuring HRQOL pre-season will provide clinicians and coaches with information necessary to identify athletes at risk for impaired HRQOL before and after a concussion.

Further, a comprehensive HRQOL measure may allow clinicians and coaches to refer athletes for individualized, targeted rehabilitations, such as psychosocial techniques including psychotherapy,³³ mindfulness meditation,³⁴ and/or yoga³⁴ that are positively impactful for HRQOL in those with and without concussion.^{33–37} Overall, clinicians should work to embed pre-existing mental health conditions and/or mental health symptom reports into an athlete's pre-season sports physical (a protocol required by most youth and adolescent level athletics).

Our findings build on previous work indicating the specific presence of EBS persistently post-concussion

(i.e., those with EBS worse than before injury) is associated with lower HRQOL at one month after injury not just compared with those with no symptoms (psychosocial MD = -22.71, physical MD = -21.03, and total MD = -22.10), but also compared with those with symptoms similar to pre-concussion levels (psychosocial MD = -14.81, physical MD = -12.59, and total MD = -14.04).^{9,38,39}

Previous research among adolescents suggests increased overall concussion symptom severity was associated with lower HRQOL 30 days post-concussion.⁹ In addition, increased behavioral symptoms were associated with lower satisfaction of life post-concussion.³⁹ In adults with persistent concussion symptoms, increased depression, anxiety, and fatigue levels were predictors of lower HRQOL.³⁸ Our work builds on these current findings by: (1) identifying EBS expression using a commonly used concussion symptom scale, making findings directly translatable to clinicians; and (2) expanding the association between HRQOL and psychological concussion outcomes to adolescent athletes.

In addition, similar to previous literature, not all adolescents in the current study experienced EBS after concussion. Specifically, 42.55% did not report any presence of EBS, and the smallest proportion of adolescents reported EBS worse than before their concussion (27.23%). These findings highlight that many individuals do not have these prolonged symptoms; however, for those who do, they support the need for future research aimed to identify patients who report EBS post-injury and future interventions designed to improve their HRQOL post-concussion.

Concussion results in physical impairments and psychological changes, both of which impact one's quality of life.² In addition, persistent concussion symptoms present athletes with continued psychological deficits^{10,11} placing students out of school¹² and athletes out of sport¹³ longer than those without persistent symptoms. This time lost greatly impacts adolescents as they are developing as students in the classroom and athletes in sports. Further, social engagement at the adolescent level frequently occurs in the classroom and during team sports. Missing time in school and sport could lead to decreased engagement with friends, impacting societal engagement and overall quality of life. Results from the current study provide evidence supporting the assessment of EBS pre- and post-concussion, information necessary to identify patients who may benefit from psychosocial-focused interventions.

When reviewing our results with published literature concerning normative values for HRQOL in adolescent athletes (Table 5),⁴⁰ our data in the no parent-reported EBS group were similar to the normal range for healthy individuals. Those with at least one parent-reported EBS at pre-concussion levels, however, had scores slightly below the normative range. Further, scores for adolescents

Table 5. Means and Standard Deviations for Health-Related Quality of Life for Male and Female Adolescent Athletes with No Emotional and Behavioral-Related Symptoms, Emotional and Behavioral-Related Symptoms at Pre-Concussion Levels, and Emotional and Behavioral-Related Symptoms Worse than Pre-Concussion and Normative Values for Health-Related Quality of Life in Adolescents

| | No EBS | | Pre-concussion EBS | | Worse EBS | | Male norm values ⁴⁰ | Female norm values ⁴⁰ |
|---------------------------------|-----------|-----------|--------------------|-----------|-----------|-----------|--------------------------------|----------------------------------|
| | Male | Female | Male | Female | Male | Female | | |
| | Mean ± SD | | | | | | Mean range | |
| Psychosocial HRQOL ^a | 98.9±9.5 | 89.1±12.2 | 82.7±10.7 | 83.9±11.6 | 69.7±14.6 | 67.6±14.0 | 87.6-92.4 | 88.5-90.4 |
| Physical HRQOL ^a | 93.7±9.8 | 87.5±12.2 | 82.0±18.1 | 83.7±11.6 | 74.7±19.7 | 65.7±19.2 | 92.3-95.6 | 90.0-92.9 |
| Total HRQOL ^a | 93.2±8.6 | 89.1±12.2 | 82.5±12.1 | 83.8±12.6 | 71.4±14.7 | 67.0±14.7 | 89.4-93.6 | 89.5-91.0 |

EBS, emotional behavioral-related persistent concussion symptoms; SD = standard deviation; HRQOL, health-related quality of life.

^aPsychosocial, physical, and total HRQOL ranged from 0–100.

with at least one parent-reported EBS worse than pre-concussion appear below the normative range. While we did not statistically compare these values, our findings, in conjunction with this previous literature, highlight those with more significant EBS symptoms have lower HRQOL at one-month post-concussion.

Limitations and future directions

This study included adolescent athletes from three concussion clinics located in the same geographical region, potentially limiting generalizability beyond the region. The study sample was 90.64% Caucasian, a racial proportion not representative of all adolescent athletes. Future research should aim to include more geographic regions and diversify cultural and racial representation within the study sample.

All data used for these analyses were parent reported. As noted, research suggests a moderate-to-strong agreement between child and parent concussion symptom reporting¹⁵ and parent proxy HRQOL.³² Future research should aim to determine the association between athlete reported EBS and HRQOL, specifically in older adolescents who may be more able to accurately report. Although the RPQ asked parents to report symptoms compared with before their child's injury, future research should aim to compare EBS expression and HRQOL reported post-injury to an adolescent's baseline measures to provide more evidence for the impact concussion has on the association between variables.

There was slight overlap between questions related to HRQOL and emotional and behavioral-related concussion symptoms, indicating a potential confounder in the association between the measures. Specific overlap with the measures used in this study (RPQ for concussion symptoms and PedsQL™ for HRQOL) include questions related to feeling depressed, impatience, restlessness, and poor concentration. Despite this overlap, results still indicated a significant difference in mean psychosocial, physical, and total HRQOL. As such, the large difference in group means allows us to believe the overlap between measures did not impact results.

Further, our findings are beneficial to clinicians, specifically those who are unable to include a full HRQOL scale as a part of their concussion protocol, because they provide insight into when HRQOL-focused intervention is necessary utilizing only a concussion symptom scale. Future research should aim to compare EBS and HRQOL beyond one month post-injury to understand longer term relationships between the post-injury outcomes.

Conclusion

Findings from this study emphasize the importance of assessing mental health and HRQOL outcomes at pre-season and across the concussion recovery timeline. Utilizing these findings both in those with acute or persistent symptoms could improve clinical tools to identify those who may experience decreased HRQOL post-concussion, decreasing short and long-term debilitation after injury.

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Authors' Contributions

CC was involved in study design of the current analyses, data analysis, data interpretation, manuscript initial drafting, and manuscript revision and final approval; JB was involved in study design, data collection, data interpretation, and manuscript revision and final approval; JF was involved in study design, data collection, data interpretation, and manuscript revision and final approval; KR was involved in study design, data collection, data interpretation, and manuscript revision and final approval; VDM was involved in the study design and manuscript revision and final approval; MD was involved in data interpretation, manuscript initial drafting, and manuscript revision and final approval; and JRM was involved in the study

design, data analysis, interpretation, manuscript initial drafting, and manuscript revision and final approval. All authors contributed to manuscript revisions, have read and approved the final version of the manuscript, and agree with the authorship order.

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