Concussion History and the Emotional and Behavioral Dyscontrol Domains of Health-Related Quality of Life in College Students

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Context: Injury or illness can affect individual perceptions of health status and health-related quality of life (HRQOL). Concussion can result in different symptoms, impairments, and functional limitations that have been found to lower HRQOL. Furthermore, concussion is known to influence the emotional and behavioral dyscontrol domains of HRQOL in pediatric populations; however, this has yet to be explored in other populations.

Objective: To compare individuals with and those without a concussion history and (1) HRQOL and (2) the emotional and behavioral dyscontrol domains of HRQOL in college students.

Design: Cross-sectional study.

Setting: University laboratory setting.

Patients or Other Participants: Of a total of 252 participants (155 women; age = 19.95 ± 1.53 years), 76 (30.2%) had a history of concussion and 176 (69.8%) did not. For participants with a history of concussion, the mean time since injury was 5.29 ± 2.77 years.

Main Outcome Measure(s): The Patient-Reported Outcome Measures Information System (PROMIS) Global Health, version 1.1, and Quality of Life in Neurological Disorders Emotional and Behavioral Dyscontrol Short Form (Neuro-QOL).

Results: No differences were seen between median scores in individuals with and those without a history of concussion in the PROMIS Physical Health (13.0 versus 14.0; *P* = .24), PROMIS Mental Health (12.0 versus 12.0; *P* = .99), and Neuro-QOL (16.0 versus 16.0; *P* = .47) scores. Additionally, when gender was controlled, the associations between a history of concussion and PROMIS Physical Health score (odds ratio [OR] = 1.04; 95% CI = 0.43, 2.52), PROMIS Mental Health score (OR = 0.66; 95% CI = 0.13, 3.25), and Neuro-QOL score (OR = 1.16; 95% CI = 0.66, 2.04) were not significant.

Conclusions: Preliminary findings suggested that the emotional and behavioral dyscontrol domains were not influenced by a concussion history of > 1 year in college-aged participants. Future researchers should continue to explore specific HRQOL domains affected by concussion as well as the influences of prior mental health conditions and behavioral dysfunction after a subsequent injury.

Key Words: mild traumatic brain injury, psychological health, athletes

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Key Points

- To our knowledge, we are the first to examine concussion history and the emotional and behavioral dyscontrol domains of health-related quality of life in college-aged participants using the Quality of Life in Neurological Disorders Emotional and Behavioral Dyscontrol Short Form.
- No differences were noted between college students with and those without a history of concussion on global health and emotional and behavioral dyscontrol health-related quality of life measures.
- Emotional and behavioral dyscontrol may not be relevant to those without a recent previous concussion but should warrant future research in individuals currently experiencing a concussion.

Concussion, and more specifically sport-related concussion, is becoming an increasingly popular topic in the global medical literature due to increasing awareness of its occurrence and unique symptom presentation. Concussion is associated with a variety of symptoms, impairments, and functional limitations, including headache, confusion, dizziness, nausea, memory loss, and impaired mental processing.[1] Furthermore, concussion results in impairments in motor control, vision, and cognition[2] that can result in functional limitations related to physical activity, academic activity, electronic use, work, and social activity.[3] Additionally,

females may experience more concussion symptoms (ie, neurocognitive functioning, irritability, and sadness) than males.[4] Collectively, the presence of symptoms, impairments, and functional limitations may affect the lives of individuals regarding sport participation, activities of daily living, and overall well-being. Consequently, these outcomes of concussion may have serious effects on health-related quality of life (HRQOL).[5]

Health-related quality of life is defined as a combination of the "patient's functional ability as well as the social and psychological abilities that allow them to fulfill their expected

roles in society."[6] Essentially, this is the individual's perception of overall functioning and well-being. Numerous domains of quality of life, including physical, psychological, and social relationships, can be influenced by the environment, personal experiences, expectations, and perceptions.[7,8] Among patients with concussion, a history of concussion was associated with lower HRQOL[5,9] and patients demonstrated lower HRQOL in the acute phase after concussion.[10–12] Collegiate athletes who reported a history of concussion scored lower on the Short Form 36 domains of bodily pain, vitality, and social functioning, indicating that concussion history had a negative effect on HRQOL.[5] Other authors[11–13] observed that the physical (eg, bodily pain and headache), psychological (eg, anxiety and depression), and social (eg, work, school, or social events) domains of HRQOL were also negatively affected by concussion. Furthermore, several groups[10,13] determined that symptom severity after concussion was correlated with HRQOL and that HRQOL may fluctuate with the time point after injury in collegiate populations. However, specific domains of HRQOL, such as emotional and behavioral dyscontrol associated with psychological health, that may still be negatively affected by concussion have yet to be explored.

Each domain of HRQOL has subdomains that can be influenced by the individual patient's beliefs, perceptions, values, and experiences.[7] *Emotional and behavioral dyscontrol* is a subdomain of psychological health that is defined by inattention, an inability to adjust to external changes due to concussion (ie, missed school or sport), an inability to control temper, impatience, irritability, and conflict with self or others.[14] Concussion may lead to behavioral and emotional difficulties in pediatric cohorts,[14] as internal problems exacerbated by concussion symptoms (eg, anxiety and depression) may cause children to be more vulnerable to behavioral problems. However, few researchers have examined this in other populations, such as college-aged individuals.

Despite the significant amount of evidence supporting the effect of concussion on various domains of HRQOL, the influence of concussion on the emotional and dyscontrol domains, specifically in college-aged populations, has yet to be investigated. Therefore, the purpose of our study was to compare the effects of self-reported concussion history on HRQOL and, more specifically, the emotional and behavioral dyscontrol associated with the psychological domain of HRQOL in college students. Additionally, we sought to predict which individuals with a history of concussion would have greater odds of better or worse HRQOL than individuals without a history of concussion based on self-reported gender and a previous diagnosis of depression or anxiety. We hypothesized that (1) individuals with a history of concussion (athletes and nonathletes) would score worse on the Patient-Reported Outcome Measures Information System (PROMIS) Global Health, version 1.1, Physical Health (PROMIS PH) and PROMIS Mental Health (PROMIS MH) and better on the Quality of Life in Neurological Disorders Emotional and Behavioral Dyscontrol Short Form (Neuro-QOL) than individuals without a history of concussion and (2) individuals with a history of concussion (athletes and nonathletes) would have a higher probability of lower perceptions of HRQOL than individuals without a history of concussion.

METHODS

Participants

A cross-sectional sample of college students enrolled in a Department of Kinesiology course at Michigan State University was recruited. Recruits were asked if they had ever been diagnosed with a concussion; however, they were not required to provide documentation, and thus concussion history was self-reported. Participants were then grouped according to whether they had a previous concussion or not (ie, concussion history or no concussion history). A paragraph describing the terms of consent was presented at the start of the survey, and completion of the survey implied consent to participate. This study was exempt from institutional review board approval, as all data were deidentified. Participants were not offered any incentives or compensation for their involvement.

Instrumentation

The primary measures were the demographic form, including medical history (eg, prior diagnosis of depression or anxiety or both, attention-deficit disorder or attention-deficit/ hyperactivity disorder, a learning disorder or dyslexia, a headache or migraine disorder, or motion sickness) and sport participation history (eg, current or past participation in a sport), the PROMIS, and the Neuro-QOL.

The PROMIS Global Health Instrument. The PROMIS is a 10-question inventory that measures global health concepts, including physical, mental, and social well-being.[15] This scale was designed to be convenient and easily understood and to decrease the burden on patients, clinicians, and researchers. Items on the PROMIS focus on 5 domains: (1) physical functioning, (2) fatigue, (3) pain, (4) emotional distress, and (5) social role.[15] Four items on the PROMIS assess global physical health,[16] which can include physical function, physical symptoms, sleep function, and sexual function.[15] Additionally, 4 items measure global mental health,[16] which includes emotional distress, cognitive function, and positive psychological function.

The PROMIS uses a Likert-style scale of answers with *excellent*, *very good*, *good*, *fair*, and *poor* options for general questions and *never*, *rarely*, *sometimes*, *often*, and *always* options for questions relating to the past 7 days. Item groups are scored for the PROMIS PH (4 items) and PROMIS MH (4 items). Each component is then scored individually and raw scores are converted to standardized t score values; the score (mean $\pm$ SD) of 50 $\pm$ 10 points represents the general US population.[17] Higher scores on the PROMIS indicate better outcomes in terms of higher perceived quality of life, physical function, and mental health, whereas lower scores indicate worse outcomes for perceived quality of life, physical function, and mental health. We chose the PROMIS because of its reliability and validity in measuring HRQOL in public populations as well as its efficient, flexible, and precise measurement of patient-reported outcomes (PROs).[15] Furthermore, other authors have used different versions of the PROMIS (eg, sleep and fatigue measures) in populations of individuals with brain injuries and found very good internal consistency (all α values of ≥0.80), and acceptable test-retest reliability (all r values of ≥0.70).[18] Although the PROMIS Global Health tool has been used to detect physical and mental health impairments in former American football

players,[19] to our knowledge, this is the first time version 1.1 has been used in concussion research.

Neuro-QOL: Emotional and Behavioral Dyscontrol. The Neuro-QOL is a compilation of 13 brief surveys used in clinical research to measure HRQOL in individuals with neurologic disorders.[20] The Emotional and Behavioral Dyscontrol Short Form is an 8-item bank that was designed to estimate a patient's health status.[20] For this study, we administered the emotional and behavioral dyscontrol form, which measures disinhibition, emotional lability, irritability, impatience, and impulsiveness.[21]

Similar to the PROMIS, the Neuro-QOL uses a Likert-style scale of answers, with *never*, *rarely*, *sometimes*, *often*, and *always* options to report on health in the past 7 days. Raw scores on the scale are converted to standardized *t* scores, with a mean score of 50 ± 10 points representing the general US population. Higher scores indicate better outcomes for the presence of the factors listed above, whereas lower scores indicate better outcomes for the absence of these factors, meaning that a higher score will indicate better likelihood of the presence of emotional and behavioral dyscontrol features. The Neuro-QOL was chosen because of its reliability[22,23] (eg, high reliability in individuals with epilepsy, Cronbach α = 0.93 and intraclass correlation coefficient [ICC] = 0.84[22]; and high reliability with Cronbach α = 0.91 and ICC = 0.78[23]) and validity[20] in populations of adults with neurologic disorders.

Procedures

This survey was administered using Michigan State University Qualtrics (Qualtrics). Graduate assistants in the Department of Kinesiology were contacted via email and Microsoft Teams (Microsoft Corp) to distribute the survey to their students. A follow-up email and Microsoft Teams message were sent to the graduate assistants to remind them to distribute the survey to their students, and participants were orally reminded by the graduate assistants to complete the survey. The survey was distributed to participating students via email or the university's online learning system for easy accessibility. The survey consisted of demographic information, medical history, concussion history, sport participation history, a symptom scale, the PROMIS, and the Neuro-QOL.

Statistical Analyses

Data collected from the Qualtrics survey were exported into an Excel spreadsheet (version 2307; Microsoft Corp). Missing data were removed, and then the remaining data were transferred to SPSS (version 27; IBM Corp) for analysis. Participants were first grouped according to self-reported concussion history or no concussion history. We performed χ^2 tests to identify differences in categorical data (eg, race or ethnicity, year in school, medical history, current medications, and sport participation). Preliminary Kolmogorov-Smirnov and Shapiro-Wilk tests revealed nonnormality of the data, so nonparametric tests were used to assess group differences. Median scores and 25th and 75th interquartile ranges (IQRs) were calculated for all outcome measures, and Mann-Whitney *U* tests were conducted to evaluate group differences for each measure. Raw scores on the outcome measures were then converted to standardized *t* scores and dichotomized as *high* (*t* score of >50) or *low* (*t* score of <50). We computed a univariable logistic regression to assess associations between

a history of self-reported concussion and the PROMIS PH, PROMIS MH, and Neuro-QOL scores. Additionally, multivariable logistic regressions were conducted to evaluate associations between a history of self-reported concussion and PROMIS PH, PROMIS MH, and Neuro-QOL scores while controlling for possible confounding factors, such as gender and a history of depression or anxiety. Model fit for logistic regression analyses was determined based on the significance of the adjusted odds ratios (ORs) and the 95% CIs for each predictor variable. The significance level was set a priori at $P < .05$ for all analyses.

RESULTS

Demographic Characteristics

A total of 302 individuals were recruited for the survey; however, only 252 individuals finished it, for a completion rate of 83.4%. Therefore, we analyzed the responses of 252 college student participants (age = 19.95 ± 1.53 years; 62% women). Among these participants, 176 (69.8%) reported no concussion history, and 76 (30.1%) reported a history of ≥1 concussions (time since most recent concussion = 5.29 ± 2.77 years). Among the group with no concussion history, 75 (53% men) participants indicated that they currently played a sport compared with 36 (50% men) in the group with a concussion history. Differences between groups were noted for race or ethnicity and medical history, with a greater proportion of non-Hispanic White participants (73.7% versus 59.1%, $P < .05$) and a greater proportion of participants with depression or anxiety (31.6% versus 15.34%, $P < .05$) in the group with a concussion history than in the group with no concussion history. Demographic characteristics of the groups are provided in Table 1.

Quality of Life Between Groups

We found no differences in median [IQR] scores between the concussion history and no concussion history groups, respectively, on the PROMIS PH (13.0 [12.0–14.0] versus 14.0 [12.25–15.0], $P = .24$), PROMIS MH (12.0 [10.0–13.75] versus 12.0 [10.0–13.0], $P = .99$), or Neuro-QOL (16.0 [12.0–20.0] versus 16.0 [12.0–19.0], $P = .47$; Table 2). Furthermore, no differences were observed between men and women in these groups. The *t* scores for both groups were lower than for the general US population on all outcome measures except for female participants in the group with no concussion history on the Neuro-QOL (Figure). When we evaluated only individuals who played a sport, no differences were demonstrated between those with and those without a history of concussion, respectively, on the PROMIS PH (13.0 [13.0–14.75] versus 14.0 [13.0–15.0], $P = .21$), PROMIS MH (12.0 [10.0–14.0] versus 12.0 [10.0–14.0], $P = .98$), or Neuro-QOL (15.0 [12.0–20.0] versus 15.0 [11.0–19.0], $P = .78$; Table 3).

Univariable logistic regression results are displayed in Table 4 for outcomes on the PROMIS PH, PROMIS MH, and Neuro-QOL. Individuals without a history of concussion were considered the reference group, and the results indicated that a concussion history was not significantly associated with scores on the PROMIS PH, PROMIS MH, or Neuro-QOL. Higher scores on the PROMIS reflected better outcomes for HRQOL, whereas higher scores on the Neuro-QOL reflected worse outcomes for HRQOL. More specifically, individuals

Table 1. Demographic Characteristics of College Students With or Without a Concussion History[a]

	Concussion History		
	Yes (n = 76)	No (n = 176)	P Value
Variable			
Age, mean ± SD, y	20 ± 9	20 ± 8	.80
Gender	No. (%)		.83
Women	46 (60.5)	109 (61.9)	
Men	30 (39.5)	67 (38.1)	
Race or ethnicity			<.05
Asian	3 (3.9)	17 (9.7)	
More than 1 race	8 (10.5)	7 (4.0)	
Non-Hispanic Black or African American	3 (3.9)	21 (11.9)	
Non-Hispanic White	56 (73.7)	104 (59.1)	
Other, unknown, or not reported	6 (8.0)	27 (15.3)	
Year in school			.36
Freshman	9 (11.8)	39 (22.2)	
Sophomore	23 (30.3)	48 (27.3)	
Junior	19 (25.0)	44 (25.0)	
Senior	22 (29.0)	39 (22.2)	
Fifth-year senior	3 (3.9)	5 (2.8)	
Medical history			.05
Depression or anxiety	24 (31.6)	27 (15.3)	
Attention-deficit or attention-deficit/ hyperactivity disorder	4 (5.3)	10 (5.7)	
Other	9 (11.8)	26 (14.8)	
No pertinent medical conditions	39 (51.32)	113 (64.2)	
Current medications			.13
Yes	33 (43.4)	59 (33.5)	
No	43 (56.6)	117 (66.5)	
Current sport participation			.49
Yes	36 (47.4)	75 (42.6)	
No	40 (52.6)	101 (57.4)	

with a history of concussion had higher odds of scoring higher on the PROMIS PH (OR = 1.04, 95% CI = 0.43, 2.52) and the Neuro-QOL (OR = 1.14, 95% CI = 0.66, 1.98) than individuals without a history of concussion but lower odds of scoring higher on the PROMIS MH (OR = 0.65, 95% CI = 0.13, 1.98); however, these associations were not significant. We applied multivariable logistic regression to determine the association of a history of concussion with PROMIS PH, PROMIS MH, and Neuro-QOL scores while controlling for

gender and depression or anxiety; nonetheless, the associations remained insignificant (Table 5).

Quality of Life According to the Number of Concussions

Participants in the concussion history group were separated into those who had multiple concussions (n = 41; 61% women) and those who had 1 concussion (n = 35; 60% women), as shown in Table 6. No differences were evident between individuals with a history of multiple concussions and individuals with 1 concussion, respectively, on the PROMIS PH (13.0 [12.0–15.0] versus 13.0 [13.0–14.0], P = .77), PROMIS MH (12.0 [10.0–13.0] versus 12.0 [9.5–14.0], P = .52), and Neuro-QOL (17.0 [12.0–19.0] versus 15.0 [11.5–20.0], P = .17).

DISCUSSION

The primary purpose of our study was to compare the effects of a self-reported concussion history on the physical and mental components of HRQOL and the emotional and behavioral dyscontrol domains of HRQOL in college-aged students. Overall, our hypotheses were not supported. We found no statistical differences between having a history of concussion and not having a history of concussion on measures of HRQOL and the emotional and behavioral dyscontrol domains of HRQOL in college-aged students. Additionally, regarding the effect of concussion history on the outcome measures between demographic variables such as gender and sport participation, no differences were identified. Although insignificant, these findings do contribute to the current gaps in the postconcussion HRQOL literature. Emotional and behavioral dyscontrol is a domain of HRQOL that has been little explored in postconcussion research, and, because our work included a population that was years removed from their most recent concussion, we can focus current investigations on injuries in the acute phase.

Emotional and Behavioral Dyscontrol

To our knowledge, we are the first to examine concussion history and the emotional and behavioral dyscontrol domains of HRQOL in college-aged participants using the

Table 2. Health-Related Quality of Life Outcomes of College Students With or Without a Concussion History[a]

	Concussion History				
	Yes		No		
Outcome	Raw Score	t Score	Raw Score	t Score	P Value
Patient-Reported Outcome Measures Information System Global Health, version 1.1					
Physical Health	13.0 (9.0)	42.3 ± 4.2	14.0 (12.0)	44.9 ± 4.3	.24
Women	13.0 (9.0)	42.3 ± 4.2	14.0 (12.0)	44.9 ± 4.3	.06
Men	14.0 (5.0)	44.9 ± 4.3	13.0 (9.0)	42.3 ± 4.2	.53
Mental Health	12.0 (3.0)	41.1 ± 3.6	12.0 (13.0)	41.1 ± 3.6	.99
Women	11.5 (13.0)	41.1 ± 3.6	11.0 (13.0)	41.1 ± 3.6	.44
Men	12.0 (10.0)	43.5 ± 3.6	12.0 (8.0)	43.5 ± 3.6	.25
Quality of Life in Neurological Disorders Emotional and Behavioral Dyscontrol Short Form					.47
Women	16.0 (20.0)	49.4 ± 2.4	17.0 (25.0)	50.7 ± 2.4	.84
Men	16.0 (17.0)	49.4 ± 2.4	14.0 (17.0)	46.7 ± 2.4	.25

[a] Raw scores are reported as median (range). Converted t scores are reported as general population mean ± SE.
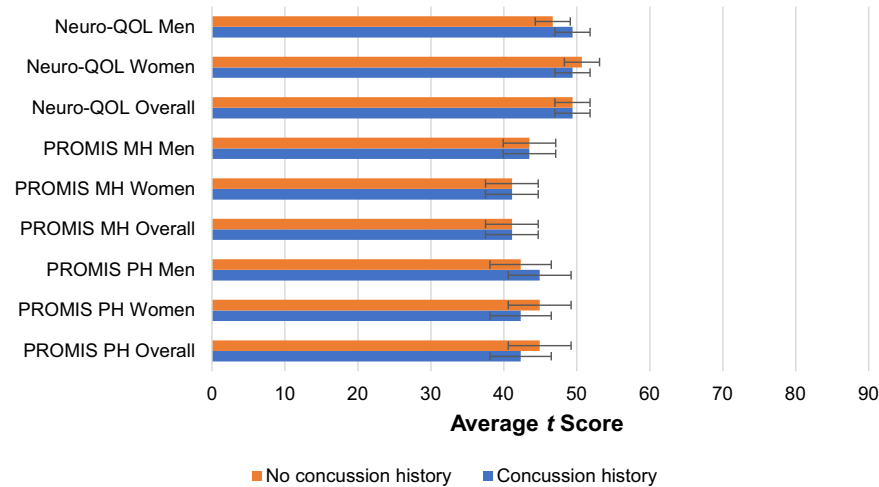
Figure. Converted *t* scores for the concussion history group and the no concussion history group. The *t* scores are reported as the general US population mean ± SE for outcome measurements for college students. Scores > 50 on the Patient-Reported Outcome Measures Information System (PROMIS) Global Health, version 1.1, indicate better functioning than the general US population in the United States. Scores >50 on the Quality of Life in Neurological Disorders Emotional and Behavioral Dyscontrol Short Form (Neuro-QOL) indicate worse functioning than the general US population. Abbreviations: MH, Mental Health; PH, Physical Health.

Table 3. Health-Related Quality of Life Outcomes of College Students With or Without a Concussion History in Students Who Currently Played a Sport[a]

| | Concussion History | | | | |
| | Yes (n = 36) | | No (n = 75) | | |
Outcome	Raw Score	*t* Score	Raw Score	*t* Score	*P* Value
Patient-Reported Outcome Measures Information System Global Health, version 1.1					
Physical Health	13.0 (9.0)	42.3 ± 4.2	14.0 (7.0)	44.9 ± 4.3	.21
Women	13.0 (9.0)	42.3 ± 4.2	14.0 (6.0)	44.9 ± 4.3	.09
Men	13.0 (5.0)	42.3 ± 4.2	14.0 (7.0)	44.9 ± 4.3	.95
Mental Health	12.0 (13.0)	43.5 ± 3.6	12.0 (13.0)	43.5 ± 3.6	.98
Women	12.5 (9.0)	45.8 ± 3.6	11.0 (13.0)	41.1 ± 3.6	.10
Men	11.0 (10.0)	41.1 ± 3.6	12.0 (5.0)	43.5 ± 3.6	.09
Quality of Life in Neurological Disorders Emotional and Behavioral Dyscontrol Short Form	15.0 (20.0)	48.1 ± 2.4	15.0 (22.0)	48.1 ± 2.4	.78
Women	15.0 (20.0)	48.1 ± 2.4	17.0 (22.0)	50.7 ± 2.4	.24
Men	15.5 (16.0)	48.1 ± 2.4	14.0 (15.0)	46.7 ± 2.4	.12

[a] Raw scores are reported as median (range). Converted *t* scores are reported as general population mean ± SE.

Neuro-QOL. The authors of several systematic reviews[24–26] on the psychological sequalae of concussion have shown that emotional dysfunction, behavioral problems, impulsivity, and aggression are among the factors that influence the incidence and severity of sport-related concussion. Comparing our results with those of previous researchers, we expected that college-aged participants with a history of concussion would be associated with increased emotional and behavioral dyscontrol. Gornall et al[14] investigated behavioral and emotional difficulties (eg, inability to participate in normal

Table 4. Univariable Logistic Regression Results for Health-Related Quality of Life Scores in College Students With a Concussion History

Outcome	Odds Ratio	95% CI	*P* Value
Patient-Reported Outcome Measures Information System Global Health, version 1.1			
Physical Health	1.03	0.43, 2.49	.94
Mental Health	0.65	0.13, 3.22	.60
Quality of Life in Neurological Disorders Emotional and Behavioral Dyscontrol			
Short Form	1.14	0.66, 1.98	.64

Table 5. Multivariable Logistic Regression Results for Health-Related Quality of Life Scores in College Students With a Concussion History While Controlling for Gender

Outcome	Odds Ratio	95% CI	*P* Value
Patient-Reported Outcome Measures Information System Global Health, version 1.1			
Physical Health	1.04	0.43, 2.52	.93
Mental Health	0.66	0.13, 3.25	.61
Quality of Life in Neurological Disorders Emotional and Behavioral Dyscontrol			
Short Form	1.16	0.66, 2.04	.61

Table 6. Health-Related Quality of Life Outcomes for College Students With a History of 1 or >1 Concussions[a]

| | Concussions | | | | |
| | One (n = 35) | | Multiple (n = 41) | | |
Outcome	Raw Score	t Score	Raw Score	t Score	P Value
Patient-Reported Outcome Measures Information System Global Health, version 1.1					
Physical Health	13.0 (5.0)	42.3 ± 4.2	13.0 (9.0)	42.3 ± 4.2	.77
Women	13.0 (5.0)	42.3 ± 4.2	13.0 (9.0)	42.3 ± 4.2	.96
Men	13.5 (4.0)	44.9 ± 4.3	14.0 (5.0)	44.9 ± 4.3	.58
Mental Health	12.0 (12.0)	43.5 ± 3.6	12.0 (12.0)	43.5 ± 3.6	.52
Women	11.0 (5.0)	41.1 ± 3.6	12.0 (12.0)	43.5 ± 3.6	.14
Men	12.0 (10.0)	43.5 ± 3.6	11.0 (7.0)	41.1 ± 3.6	.36
Quality of Life in Neurological Disorders Emotional and Behavioral Dyscontrol Short Form	17.0 (19.0)	50.7 ± 2.4	15.0 (20.0)	48.1 ± 2.4	.17
Women	17.0 (19.0)	50.7 ± 2.4	15.0 (20.0)	48.1 ± 2.4	.41
Men	17.0 (17.0)	50.7 ± 2.4	13.5 (15.0)	44.9 ± 4.3	.23

[a] Raw scores are reported as median (range). Converted t scores are reported as general population mean ± SE.

activities, such as school, sport, and social settings; irritability; inattention; and inability to control and express emotions) in a pediatric population with concussion. They observed that internalizing, externalizing, and total behavioral problems were worse in the acute phase (ie, 2 weeks after injury) and were significantly reduced by 3 months after concussion. These results suggest that pediatric concussion is associated with emotional and behavioral disturbances acutely that will likely improve over time. However, we demonstrated no differences between college-aged participants with and those without a history of concussion on the Neuro-QOL.

The lack of statistical significance in this study might be a result of age, gender, time since injury, and sport participation, as we identified no associations of a history of concussion with the HRQOL measures while controlling for gender and no differences by sport participation. Greater impulsivity and risk taking has been linked with adolescence,[27] so as individuals age, they may exert better control of their emotions and behaviors. Additionally, a person who no longer engages in sports and does not identify as an athlete may no longer feel the pressure or stress to fulfill that role, which may result in HRQOL being unaffected. Individuals also may no longer experience maladaptive mental health outcomes for such extended periods of time after injury, as it seems that such mental health outcomes associated with concussion are most prevalent in the acute phase or a few months after injury.[24,25] These preliminary findings suggest that emotional and behavioral dyscontrol may not be relevant to those without a recent previous concussion but should warrant future examination in college-aged individuals and athletes currently experiencing a concussion.[24–26]

Overall HRQOL

Furthermore, we explored how a self-reported concussion history affected the physical and mental health domains of HRQOL on the PROMIS Global Health scale. Although earlier authors indicated that a reported history of concussion might have a negative effect on certain domains of HRQOL,[5] others found no significant effects of acute concussion on HRQOL.[12,13] We saw no differences in HRQOL measures between those with and those without a history of concussion, as both groups scored similarly on the PROMIS PH and PROMIS MH. Kuehl et al[5] noted no differences in other domains of HRQOL, including physical functioning and mental health, which may be comparable with the physical and mental health measures of the PROMIS we collected. Moreover, Williams et al[12] observed that self-reported sport-related concussion was not associated with PROMIS Pediatric-25 subscale scores (eg, anxiety, depression, fatigue, physical functioning, and social relationships) on day 3 or day 10 after injury or at return to play. However, some investigators have demonstrated negative effects on the psychological health domains of HRQOL in concussed populations. Mainwaring et al[28] determined that collegiate athletes experiencing mild traumatic brain injury exhibited worse emotional reactions than control groups. Retired National Football League players with a history of ≥3 concussions were 3 times more likely to be diagnosed with depression.[29] Adolescent athletes with a history of concussion also displayed worse HRQOL scores in the psychological health domains. Presently, it seems that the domains of HRQOL most affected by concussion are social functioning, vitality, and bodily pain,[5,30,31] which may encompass aspects of the physical health and social relationship domains of HRQOL.

Given these findings, the results regarding whether concussion affects the psychological domains of HRQOL have been mixed. This may be attributed to the type of PRO used to measure the HRQOL domains. Certain PROs, such as the Short Form 36 and PROMIS, are *global health measures*, which are general tools that address a broad scope and several dimension of HRQOL.[32] Yet more specific PROs, such as the Profile of Mood States used by Mainwaring et al,[28] may be more sensitive to measuring changes in specific outcomes (eg, psychological health).[33] Optimal patient care includes evaluation of both generic and specific outcomes to best measure the disease or condition and dimensions of interest.[33] In conclusion, we should continue to explore the psychological domain of HRQOL and focus on determining which patients might be affected most by this domain, as it has implications for the assessment and management of concussion.

Clinical Implications

Our results indicate that clinicians need not be concerned about emotional and behavioral dyscontrol throughout the recovery process of college-aged individuals who have a

history of concussion. Although these findings are not consistent with those of several systematic reviews that identified psychological and emotional concerns after concussion[24–26] in other populations (eg, pediatric),[14] we are the first to examine these domains of HRQOL in a collegiate population. Therefore, clinicians might consider continuing to incorporate patient-centered care focused on improving HRQOL in other populations, but in college-aged individuals, further study is necessary to determine if the emotional and behavioral domains are truly affected. Clinicians can incorporate HRQOL into their baseline testing to detect preinjury mental health risk factors (ie, depression and anxiety).[34] Furthermore, measuring HRQOL during baseline testing and at the postinjury assessments enables clinicians to make referrals to other health care professionals (ie, sport psychologists) and implement more individualized treatment and rehabilitation protocols after a concussion.

Limitations and Future Research

The current study was not without limitations. First, a larger sample size would have provided greater power for the statistical analyses. Second, our findings are limited to college-aged individuals, and, thus, the results should not be generalized to other populations. Additionally, our population was not entirely "athletic," and it would be beneficial to assess the emotional and behavioral domains of HRQOL specifically in collegiate athletes. As with most survey-based research, our data were self-reported, and participants may not have been fully transparent (ie, underreporting or overreporting) or may have misunderstood the questions, which could have led to bias. For the group with a history of concussion, the substantial time since the most recent concussion (5.29 ± 2.77 years) was not factored into the regression models and could explain the lack of differences between groups. We did not inquire about psychological or mental health services received after their most recent concussion, which might have altered the reporting of HRQOL as well. Therefore, future researchers of HRQOL in college students should explore the influence of a more recent concussion history (within 1 to 2 years) on the emotional and behavioral dyscontrol domains, along with any HRQOL-specific treatment or services that have been received. Future authors should continue to evaluate specific domains of HRQOL that are affected by concussion and develop a concussion-specific HRQOL measure for more targeted assessment and management.

Although reliability and validity data are available for various versions of the PROMIS and the Neuro-QOL in populations with brain injuries[18] and similar conditions (eg, epilepsy,[22] multiple sclerosis[23]), to our knowledge, no reliability and validity data exist for the use of the PROMIS Global Health, version 1.1, and Neuro-QOL in populations with concussion. Also, the convergent validity of the PROMIS Global Health, version 1.1, and Neuro-QOL Emotional and Behavioral Dyscontrol Short Form has yet to be determined in populations with concussions or other brain injuries. However, Fox et al[35] found that the PROMIS and another version of the Neuro-QOL (Neuro-QOL Stigma item bank) displayed strong and consistent correlations (most P values $< .001$). Furthermore, in individuals with epilepsy, the Neuro-QOL Emotional and Behavioral Dyscontrol Short Form exhibited high convergent validity with similar HRQOL constructs ($P < .01$ for most correlations between related measures).[22]

Also, Hwang et al[36] identified high convergent validity of the PROMIS Global Health, version 1.1, with similar HRQOL constructs ($P < .01$ for all correlations). Future investigators might consider addressing the psychometric properties and convergent validity of the PROMIS Global Health, version 1.1, and Neuro-QOL specifically in populations with concussion.

CONCLUSIONS

We studied how a self-reported concussion history affected HRQOL and, more specifically, the emotional and behavioral dyscontrol associated with the psychological domain of HRQOL in college students. Our findings suggested that the emotional and behavioral dyscontrol domains were not influenced by a concussion history in a college-aged population. Although these results were insignificant, we were the first to measure these domains of HRQOL in a population other than pediatric individuals and our work therefore contributes to the understanding of the effect of a history of concussion on HRQOL in different populations. Future researchers should continue to assess the HRQOL domains most affected by concussion as well as the influence of prior mental health conditions and behavioral dysfunction on a subsequent injury. This information will further advise clinicians of the most appropriate patient-centered care to prescribe after concussion.

REFERENCES

1. McCrory P, Meeuwisse WH, Dvorak J, et al. 5th International Conference on Concussion in Sport (Berlin). *Br J Sports Med*. 2017;51(11):837. doi:10.1136/bjsports-2017-097878
2. Brown JA, Dalecki M, Hughes C, Macpherson AK, Sergio LE. Cognitive-motor integration deficits in young adult athletes following concussion. *BMC Sports Sci Med Rehabil*. 2015;7:25. doi:10.1186/s13102-015-0019-4
3. Kontos AP, Sufrinko A, Sandel N, Emami K, Collins MW. Sport-related concussion clinical profiles: clinical characteristics, targeted treatments, and preliminary evidence. *Curr Sports Med Rep*. 2019;18(3):82–92. doi:10.1249/jsr.0000000000000573
4. Covassin T, Savage JL, Bretzin AC, Fox ME. Sex differences in sport-related concussion long-term outcomes. *Int J Psychophysiol*. 2018;132(pt A):9–13. doi:10.1016/j.ijpsycho.2017.09.010
5. Kuehl MD, Snyder AR, Erickson SE, Valovich McLeod TC. Impact of prior concussions on health-related quality of life in collegiate athletes. *Clin J Sport Med*. 2010;20(2):86–91. doi:10.1097/JSM.0b013e3181cf4534
6. Snyder CF, Mathias SD, Cella D, Isitt JJ, Wu AW, Young J. Health-related quality of life of immune thrombocytopenic purpura patients: results from a web-based survey. *Curr Med Res Opin*. 2008;24(10):2767–2776. doi:10.1185/03007990802377461
7. Testa MA, Simonson DC. Assessment of quality-of-life outcomes. *N Engl J Med*. 1996;334(13):835–840. doi:10.1056/NEJM199603283341306
8. Arnold R, Ranchor AV, Sanderman R, Kempen GIJM, Ormel J, Suurmeijer TPBM. The relative contribution of domains of quality of life to overall quality of life for different chronic diseases. *Qual Life Res*. 2004;13(5):883–896. doi:10.1023/b:qure.0000025599.74923.f2
9. Valovich McLeod TC, Bay RC, Snyder AR. Self-reported history of concussion affects health-related quality of life in adolescent athletes. *Athl Train Sports Health Care*. 2010;2(5):219–226. doi:10.3928/19425864-20100630-02
10. Houston MN, Bay RC, Valovich McLeod TC. The relationship between post-injury measures of cognition, balance, symptom reports

and health-related quality-of-life in adolescent athletes with concussion. *Brain Inj*. 2016;30(7):891–898. doi:10.3109/02699052.2016.1146960

11. Valovich McLeod TC, Williams RM, Snyder Valier AR, Root HJ, Lam KC, Bay RC. The development and readability of the Concussion Quality Of Life Scale-Youth for assessing health-related quality of life following sport-related concussion. *Orthop J Sports Med*. 2019;7(3 suppl):2325967119S0000. doi:10.1177/2325967119s00003

12. Williams RM, Johnson RS, Snyder Valier AR, Bay RC, Valovich McLeod TC. Evaluating multiple domains of health in high school athletes with sport-related concussion. *J Sport Rehabil*. 2020;30(4): 545–551. doi:10.1123/jsr.2019-0517

13. Weber ML, Lynall RC, Hoffman NL, et al. Health-related quality of life following concussion in collegiate student-athletes with and without concussion history. *Ann Biomed Eng*. 2019;47(10):2136–2146. doi:10.1007/s10439-018-02151-7

14. Gornall A, Takagi M, Clarke C, et al. Behavioral and emotional difficulties after pediatric concussion. *J Neurotrauma*. 2020;37(1):163–169. doi:10.1089/neu.2018.6235

15. Cella D, Riley W, Stone A, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005–2008. *J Clin Epidemiol*. 2010;63(11):1179–1194. doi:10.1016/j.jclinepi.2010.04.011

16. Hays RD, Schalet BD, Spritzer KL, Cella D. Two-item PROMIS global physical and mental health scales. *J Patient Rep Outcomes*. 2017;1(1):2. doi:10.1186/s41687-017-0003-8

17. Hays RD, Bjorner JB, Revicki DA, Spritzer KL, Cella D. Development of physical and mental health summary scores from the Patient-Reported Outcomes Measurement Information System (PROMIS) global items. *Qual Life Res*. 2009;18(7):873–880. doi:10.1007/s11136-009-9496-9

18. Carlozzi NE, Ianni PA, Tulsky DS, et al. Understanding health-related quality of life in caregivers of civilians and service members/veterans with traumatic brain injury: establishing the reliability and validity of PROMIS Fatigue and Sleep Disturbance item banks. *Arch Phys Med Rehabil*. 2019;100(4S):S102–S109. doi:10.1016/j.apmr.2018.05.020

19. Tenforde AS, Cortez B, Coughlan-Gifford E, et al. Individual and cumulative health afflictions are associated with greater impairment in physical and mental function in former professional American style football players. *PM R*. 2022;14(1):30–39. doi:10.1002/pmrj.12581

20. Cella D, Lai JS, Nowinski CJ, et al. Neuro-QOL: brief measures of health-related quality of life for clinical research in neurology. *Neurology*. 2012;78(23):1860–1867. doi:10.1212/wnl.0b013e318258f744

21. National Institute of Neurological Disorders and Stroke (NINDS). User Manual for the Quality of Life in Neurological Disorders (Neuro-QoL) Measures, version 2.0. Published 2015. Accessed September 21, 2021. www.sralab.org/sites/default/files/2017-06/Neuro-QOL_User_Manual_v2_24Mar2015.pdf

22. Victorson D, Cavazos JE, Holmes GL, et al. Validity of the Neurology Quality-of-Life (Neuro-QoL) measurement system in adult epilepsy. *Epilepsy Behav*. 2014;31:77–84. doi:10.1016/j.yebeh.2013.11.008

23. Miller DM, Bethoux F, Victorson D, et al. Validating Neuro-QoL short forms and targeted scales with people who have multiple sclerosis. *Mult Scler*. 2016;22(6):830–841. doi:10.1177/1352458515599450

24. Rice SM, Parker AG, Rosenbaum S, Bailey A, Mawren D, Purcell R. Sport-related concussion and mental health outcomes in elite athletes: a systematic review. *Sports Med*. 2018;48(2):447–465. doi:10.1007/s40279-017-0810-3

25. Wilmoth K, Tan A, Hague C, et al. Current state of the literature on psychological and social sequelae of sports-related concussion in school-aged children and adolescents. *J Exp Neurosci*. 2019; 13:1179069519830421. doi:10.1177/1179069519830421

26. Trinh LN, Brown SM, Mulcahey MK. The influence of psychological factors on the incidence and severity of sports-related concussions: a systematic review. *Am J Sports Med*. 2020;48(6):1516–1525. doi:10.1177/0363546519882626

27. Romer D. Adolescent risk taking, impulsivity, and brain development: implications for prevention. *Dev Psychobiol*. 2010;52(3):263–276. doi:10.1002/dev.20442

28. Mainwaring L, Bisschop S, Green R, et al. Emotional reaction of varsity athletes to sport-related concussion. *J Sport Exerc Psychol*. 2004;26(1):119–135. doi:10.1123/jsep.26.1.119

29. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sports Exerc*. 2007;39(6):903–909. doi:10.1249/mss.0b013e3180383da5

30. Emanuelson I, Andersson Holmkvist E, Bjorklund R, Stalhammar D. Quality of life and post-concussion symptoms in adults after mild traumatic brain injury: a population-based study in western Sweden. *Acta Neurol Scand*. 2003;108(5):332–338. doi:10.1034/j.1600-0404.2003.00155.x

31. Hutchison M, Mainwaring LM, Comper P, Richards DW, Bisschop SM. Differential emotional responses of varsity athletes to concussion and musculoskeletal injuries. *Clin J Sport Med*. 2009;19(1):13–19. doi:10.1097/JSM.0b013e318190ba06

32. Fairclough DL. Patient reported outcomes as endpoints in medical research. *Stat Meth Med Res*. 2004;13(2):115–138. doi:10.1191/0962280204sm357ra

33. Snyder AR, Valovich McLeod TC. Selecting patient-based outcome measures. *Athl Ther Today*. 2007;12(6):12–15. doi:10.1123/att.12.6.12

34. Burns K, Kerod K, McDevitt J. Previous concussions increase risk of mental health disability in college athletes. *J Clin Transl Res*. 2022;8(3):181–184.

35. Fox RS, Peipert JD, Vera-Llonch M, Phillips G, Cella D. PROMIS and Neuro-QoL measures are valid measures of health-related quality of life among patients with familial chylomicronemia syndrome. *Exp Rev Cardiovasc Ther*. 2020;18(4):231–238. doi:10.1080/14779072.2020.1748011

36. Hwang MC, Ogdie A, Puravath A, Reveille JD. Reliability and validity of Patient-Reported Outcomes Measurement Information System Short Forms in ankylosing spondylitis. *J Rheumatol*. 2020;47(8):1182–1188. doi:10.3899/jrheum.190201

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