Health-related quality of life following adolescent sports-related concussion or fracture: a prospective cohort study

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OBJECTIVE The longitudinal effects of sports-related concussion (SRC) in adolescents on health-related quality of life (HRQOL) remain poorly understood. Hence, the authors established two objectives of this study: 1) compare HRQOL outcomes among adolescents with an acute SRC or a sports-related extremity fracture (SREF) who were followed up until physician-documented clinical recovery; and 2) identify the clinical variables associated with worse HRQOL among adolescent SRC patients.

METHODS The authors conducted a prospective cohort study of adolescents with acute SRC and those with acute SREF who underwent clinical assessment and follow-up at tertiary subspecialty clinics. Longitudinal patient-reported HRQOL was measured at the time of initial assessment and at each follow-up appointment by using the adolescent version (age 13–18 years) of the Pediatric Quality of Life Inventory (PedsQL) Generic Core Scale and Cognitive Functioning Scale.

RESULTS A total of 135 patients with SRC (60.0% male; mean age 14.7 years; time from injury to initial assessment 6 days) and 96 patients with SREF (59.4% male; mean age 14.1 years; time from injury to initial assessment 8 days) participated in the study. At the initial assessment, the SRC patients demonstrated significantly worse cognitive HRQOL and clinically meaningful impairments in school and overall HRQOL compared to the SREF patients. Clinical variables associated with a worse HRQOL among SRC patients differed by domain but were significantly affected by the patients' initial symptom burden and the development of delayed physician-documented clinical recovery (> 28 days postinjury). No persistent impairments in HRQOL were observed among SRC patients who were followed up until physician-documented clinical recovery.

CONCLUSIONS Adolescent SRC is associated with temporary impairments in HRQOL that have been shown to resolve in patients who are followed up until physician-documented clinical recovery. Future studies are needed to identify the clinicopathological features that are associated with impaired HRQOL and to assess whether the initiation of multidisciplinary, targeted rehabilitation strategies would lead to an improvement in HRQOL.

<https://thejns.org/doi/abs/10.3171/2018.8.PEDS18356>

KEYWORDS health-related quality of life; sports-related concussion; fracture; adolescent; patient outcomes; trauma

RECENTLY, health-related quality of life (HRQOL) has emerged as an important outcome measure in clinical and research studies among children and adolescents with a variety of acute and chronic medical conditions. HRQOL is a multidimensional patient-report-

ed outcome that aims to measure the effect of a medical condition on the patient's perceptions of his or her physical, mental, and social functioning.³⁶ Among the suggested advantages of incorporating HRQOL measures into clinical practice and research is the opportunity to evaluate

ABBREVIATIONS ADHD = attention-deficit/hyperactivity disorder; HRQOL = health-related quality of life; IQR = interquartile range; MCID = minimal clinically important difference; mTBI = mild TBI; PCSS = Post-Concussion Symptom Scale; PedsQL = Pediatric Quality of Life Inventory; PPCS = persistent postconcussion symptoms; SRC = sports-related concussion; SREF = sports-related extremity fracture; TBI = traumatic brain injury.

SUBMITTED June 6, 2018. **ACCEPTED** August 15, 2018.

INCLUDE WHEN CITING Published online January 15, 2019; DOI: 10.3171/2018.8.PEDS18356.

the “hidden morbidity” or more subtle consequences of medical conditions or injuries on patient functioning that may not be captured by more traditional clinical outcome measures.^{1,35,37}

One condition that has the potential to result in immediate and long-term impairments in HRQOL is sports-related concussion (SRC). SRC is a form of traumatic brain injury (TBI) that often presents with a combination of symptoms that reflect disturbances in sleep and in physical, cognitive, and emotional functioning.²⁴ With proper medical assessment, education, and a gradual return to school and sport activities, most adolescents make a complete clinical recovery within 1–4 weeks.³ However, an important subset of patients experience delayed recovery and will require a multidisciplinary therapeutic approach to address the underlying pathophysiological and psychosocial causes of persistent postconcussion symptoms (PPCS).^{10,23} Preliminary studies suggest that children and adolescents with mild, moderate, and severe TBI can experience acute and persistent impairments in HRQOL.^{5,6,12–14,21,22,26–30,34,41} However, it remains unclear what clinical variables are associated with worse initial HRQOL following adolescent acute SRC and how these outcomes compare to those experienced by adolescents with injuries that are unrelated to the brain.

Accordingly, the objectives of this study were the following: 1) compare longitudinal HRQOL outcomes among adolescents who sustained an acute SRC or sports-related extremity fracture (SREF) and were followed up until physician-documented clinical recovery; and 2) identify the clinical variables associated with a worse HRQOL among adolescent SRC patients.

Methods

Study Design and Participants

We conducted a prospective cohort study of adolescents in whom acute SRC or SREF had been diagnosed. Adolescent SRC patients were recruited from the Pan Am Concussion Program, a government-funded multidisciplinary pediatric concussion program that receives patient referrals from primary care and emergency department physicians throughout Manitoba, eastern Saskatchewan, and northwestern Ontario, and also receives some patients directly due to local sport-specific concussion protocols. Adolescent SRC patients were included if they were 13–18 years of age and had received a diagnosis of acute SRC according to the definition provided in the International Concussion in Sport Consensus Statement.²⁵ Patients were excluded if they had a history of moderate or severe TBI, had sustained simultaneous structural spine injuries or orthopedic injuries, demonstrated evidence of structural traumatic intracranial injury on neuroimaging, or had PPCS (> 1 month postinjury).

Adolescent SREF patients were recruited from the Pan Am Clinic’s Minor Injury Clinic for Kids, a pediatric orthopedic injury clinic that receives referrals from primary care and emergency department physicians throughout the same geographic region for children and adolescents who sustain nonoperative extremity fractures and other orthopedic injuries. Adolescent SREF patients were included if

they were 13–18 years of age and had received a diagnosis of acute SREF based on clinical history and the results of the physical examination and diagnostic imaging. Patients with fractures involving the skull or spine, injuries requiring surgical repair, or coexisting concussions or head injuries were excluded.

SREF patients were selected to serve as a non-brain-related injury comparison group because isolated orthopedic injuries can be associated with a disruption in sport participation and impairments in physical, psychological, social, and school functioning that are independent of TBI.⁷

Clinical Assessment and Study Recruitment

All SRC patients underwent initial clinical assessment, follow-up, and medical clearance by a single neurosurgeon. At the initial clinical assessment, all patients filled out the Post-Concussion Symptom Scale (PCSS) self-assessment questionnaire, a valid and reliable symptom inventory, and underwent a clinical history and physical examination.^{17,19} Potentially eligible patients were first identified by the neurosurgeon and later approached by a research assistant, who obtained parental consent and patient assent. Follow-up appointments were arranged based on the patient’s clinical recovery rate and sport schedule, and not according to a predesignated research protocol. In general, SRC patients were considered clinically recovered when they no longer experienced symptoms at rest (or, in the case of those with preexisting conditions such as migraine or depression, had returned to their preinjury status), were tolerating full-time school and physical exercise without symptoms, had normal findings on physical examination, and had completed their graduated return-to-play protocol,²⁵ if applicable.

All SREF patients underwent their initial clinical assessment and medical follow-up by pediatric orthopedic surgeons and pediatric primary care physicians. Potentially eligible SREF patients were identified by the physician and approached by a research assistant, who obtained parental consent and patient assent. SREF patients underwent clinical follow-up based on the rate of their clinical recovery, as determined by follow-up clinical and diagnostic imaging findings. SREF patients were considered clinically recovered when satisfactory clinical and radiographic evidence of fracture healing was confirmed and the patient was cleared to return to full activities.

Data Collection and Outcome Measures

HRQOL was measured using the adolescent version (ages 13–18 years) of the Pediatric Quality of Life Inventory (PedsQL) Generic Core Scale and the PedsQL Cognitive Functioning Scale (<https://www.pedsq.org/index.html>). The PedsQL Generic Core Scale is a questionnaire that is completed by the patient in 5–10 minutes. This instrument generates 5 scores: physical (8 items), emotional (5 items), social (5 items), and school (5 items), and a total score for overall HRQOL (based on the results of all 23 items). Total and subscale PedsQL results are transformed into scores that range from 0 to 100, where higher scores reflect a better HRQOL. The PedsQL Generic Core Scale

provides a valid and reliable assessment of HRQOL in healthy children and in patients with acute and chronic medical conditions.^{4,38,40} There are normative values for healthy adolescents and minimal clinically important difference (MCID) point changes for the PedsQL total and subscale scores.³⁶ The PedsQL Cognitive Functioning Scale includes 6 items and generates a score from 0 to 100, where a higher score indicates a better cognitive functioning HRQOL.³⁹ At present, we are not aware of any established MCID point changes for the PedsQL Cognitive Functioning Scale. Both the PedsQL Generic Core Scale and Cognitive Functioning Scale have also been used to measure HRQOL in patient studies of pediatric concussion and TBI.^{13,22,27,34}

Following consent gathering, participants completed the PedsQL Generic Core Scale and Cognitive Functioning Scale at their initial clinical assessments. Participants also completed both instruments before each subsequent follow-up visit with their respective physician, including the final visit to document clinical recovery.

Time to physician-documented clinical recovery was defined as the time from injury to the final follow-up visit during which the physician documented clinical recovery of the patient's SRC or SREF. Because the current literature findings suggest that most pediatric SRC patients recover within 1 month postinjury,³ we defined delayed recovery as physician-documented clinical recovery occurring later than 4 weeks (28 days) after the date of injury.

Statistical Analysis

The distributions of baseline and injury characteristics were summarized using proportions for dichotomous/polytomous characteristics and means with standard deviations (SDs) for continuous characteristics (or medians with interquartile ranges [IQRs] for skewed data). Data in SRC and SREF patients were compared using the chi-square test, t-test, or rank-sum test as appropriate.

Mean PedsQL physical, emotional, social, school, and total scores, and mean PedsQL Cognitive Functioning Scale scores were calculated with 95% confidence intervals for both SRC and SREF patients at the initial assessment, and at the final assessment for those patients who were followed up until physician-documented medical clearance.

To determine clinical variables associated with a worse initial HRQOL among SRC patients, we used linear regression with a backward elimination approach. This was repeated for each subscore. A priori clinical predictors were entered into the model: sex; age (in years); history of previous concussion (yes/no), migraine or nonspecific headache, depression, or attention-deficit/hyperactivity disorder (ADHD); loss of consciousness at the time of injury; PCSS score at the initial assessment (transformed as the square root of the initial PCSS to account for skewness); patient's perception of his or her school's provision of adequate accommodations during recovery (yes/somewhat/no); and the development of delayed physician-documented clinical recovery. Clinical variables that were not statistically significant were independently removed from the model one at a time. The clinical variable with the highest p value was removed, provided the

variable did not confound any of the other associations between the outcome and remaining risk factors. Confounding was defined as a greater than 15% change in the estimates. This was repeated until only statistically significant clinical variables (and any confounding predictors) remained. Adolescents who were injured outside the academic year were not included in the school or overall HRQOL models.

Because patients were followed up at different intervals, the days between clinic visits were calculated to account for this variation. Mixed generalized linear modeling using maximum likelihood estimation and an unstructured covariance matrix was used to determine the change in HRQOL score in 1-week intervals. The unstructured covariance matrix included terms for random intercepts to account for varying initial HRQOL scores and random slopes representing differing rates of change in HRQOL scores over time. This accounts for the correlated nature of the data when repeatedly measuring HRQOL within each participant. Due to a significant effect modification by the development of delayed physician-documented clinical recovery among SRC patients, results are presented as patients in whom recovery was delayed and patients in whom recovery was not delayed. The potential confounding effects of age, sex, and initial PCSS score (represented as the square root of the initial PCSS score) were examined. A backward elimination modeling approach was used as described above. This process was then repeated for SREF patients. HRQOL results are presented as point increases (out of 100) per week with 95% confidence intervals, which is consistent with the manner of presentation in our previous study.³⁴

All statistical analyses were conducted using Stata version 13.0 software (StataCorp LLC). A two-sided $p < 0.05$ was deemed statistically significant.

Ethical Approval

Ethical approval was granted by the University of Manitoba Research Ethics Board.

Results

Recruitment

Between October 2014 and October 2015, 163 patients presented with acute SRC and met the inclusion criteria; however, 7 patients declined to participate, 1 only attended the first appointment, and 20 were lost to follow-up. During the same time period, 146 patients presented with acute SREF and met the inclusion criteria; however, 11 declined to participate, 9 only went to the first appointment, 27 were lost to follow-up, and 3 asked to be removed midway through the study. Overall, there were 135 SRC and 96 SREF patients included in the study.

Patient Characteristics

Adolescents who sustained an SRC were significantly older and more likely to have sustained a previous concussion than those with an SREF (Table 1). The median PCSS score at the initial assessment among SRC patients was 16 (IQR 6–39). The median number of days from injury to the initial consultation was significantly longer for SREF

TABLE 1. Baseline characteristics and initial HRQOL in adolescent patients with SRC or SREF

Characteristic*	Total (N = 231)	SRC Group (N = 135)	SREF Group (N = 96)	p Value
Age in yrs (mean $\pm$ SD)	14.5 $\pm$ 1.2	14.7 $\pm$ 1.3	14.1 $\pm$ 1.1	<0.0001
Male	138 (59.7)	81 (60.0)	57 (59.4)	0.924
History of ADHD	11 (4.8)	6 (4.4)	5 (5.2)	0.788
History of depression	9 (3.9)	7 (5.2)	2 (2.1)	0.230
History of nonspecific or migraine headaches	25 (10.8)	18 (13.3)	7 (7.3)	0.145
History of previous concussion	94 (40.7)	81 (60.0)	13 (13.5)	<0.0001
HRQOL†				
Cognitive functioning	69.55 (66.40 to 72.71)	59.66¶ (55.55 to 63.77)	83.16 (79.72 to 86.60)	<0.0001
Physical functioning	58.97‡ (55.85 to 62.08)	60.27‡ (56.09 to 64.44)	57.16‡ (52.42 to 61.91)	0.3339
Emotional functioning	76.93 (74.16 to 79.70)	75.44 (71.60 to 79.28)	79.01 (75.06 to 82.96)	0.2118
Social functioning	87.41 (85.57 to 89.25)	88.52 (86.17 to 90.87)	85.84 (82.87 to 88.81)	0.1589
School functioning§	64.35‡ (60.75 to 67.95)	56.13‡¶ (51.22 to 61.04)	75.43 (71.34 to 79.53)	<0.0001
Overall**	72.73‡ (70.30 to 75.17)	70.51‡¶ (67.09 to 73.93)	75.77‡ (72.43 to 79.11)	0.0347
Sport played at the time of injury*				
Hockey	71 (30.7)	62 (45.9)	9 (9.4)	
Football	41 (17.8)	20 (14.8)	21 (21.9)	
Soccer	34 (14.7)	18 (13.3)	16 (16.7)	
Basketball	24 (10.4)	8 (5.9)	16 (16.7)	
Other	62 (26.8)	28 (20.7)	34 (35.4)	
Initial median PCSS score (IQR)	6 to 39			

* Unless otherwise specified, each value represents the number of patients (%).

† Unless otherwise specified, each value represents the mean PedsQL score (IQR).

‡ Score indicates a clinically meaningful difference compared to healthy norms. Note: The normative data and MCIDs, respectively, for the PedsQL 4.0 Generic Core Scale scores, as reported by Varni et al.,³⁶ are as follows: physical, 87.77 and 6.66; emotional, 79.21 and 8.94; social, 84.97 and 8.36; school, 81.31 and 9.12; and overall, 83.91 and 4.36. The normative datum for the PedsQL Cognitive Functioning Scale score, as reported by Varni et al.,³⁹ is 82.08; the MCID is not reported.

§ Limited to those patients who received their injuries during the school year.

¶ A clinically meaningful worse score when compared to patients with SREF.

** Includes physical, emotional, social, and school functioning.

patients (8 days; IQR 7–10 days) than for SRC patients (6 days; IQR 5–10 days; $p = 0.0088$).

HRQOL at the Initial Assessment and at Physician-Documented Clinical Recovery

The initial PedsQL Generic Core Scale and Cognitive Functioning Scale scores are summarized in Table 1. SRC patients reported significantly worse cognitive, school, and overall HRQOL than SREF patients but no differences in physical, emotional, and social HRQOL. Compared to published normative data for healthy youths, SRC patients demonstrated worse physical, school, and overall PedsQL scores that exceeded the MCID. Compared to healthy youths, SREF patients demonstrated worse physical and overall PedsQL scores that exceeded the MCID. Worse school and overall PedsQL scores among SRC patients exceeded the MCID when compared to SREF patients.

The initial and physician-documented clinical recovery HRQOL scores are presented in Table 2. Among SRC patients, HRQOL was modified by whether patients experienced a normal or delayed physician-documented clinical recovery, and thus the results for these two groups are presented separately. Overall, HRQOL at the initial assessment was significantly worse among SRC patients who

experienced delayed recovery when compared to SRC patients who attained normal recovery and SREF patients. Lower overall PedsQL scores among SRC patients who experienced delayed recovery exceeded the MCID when compared to scores of SRC patients with a normal recovery or scores of SREF patients. At clinical recovery, the overall HRQOL returned to normal among all SRC patients and SREF patients, although overall, the HRQOL was significantly worse among SREF patients compared to both SRC groups. At the initial assessment, cognitive HRQOL was significantly lower among SRC patients who experienced delayed recovery than among SRC patients who had a normal recovery or SREF patients, and cognitive HRQOL among both groups of SRC patients was significantly worse than that among SREF patients. At clinical recovery, cognitive HRQOL returned to normal in all groups; however, SRC patients who experienced a normal recovery demonstrated significantly better cognitive HRQOL compared to SREF patients. At the initial assessment, SRC patients who experienced delayed recovery and SREF patients demonstrated similarly worse physical HRQOL compared to SRC patients who had a normal recovery. At clinical recovery, physical HRQOL returned to normal among SRC patients. However, physical PedsQL scores among SREF patients remained abnor-

TABLE 2. HRQOL at the initial assessment and at physician-documented clinical recovery among patients with SRC or SREF in whom there was complete medical follow-up

HRQOL Subscale	Injury Status Group	Initial HRQOL	Final HRQOL at Medical Clearance
Cognitive functioning	SRC delayed recovery	N = 52†§ 52.85 (46.40 to 59.31)	N = 53 90.64 (86.46 to 94.83)
	SRC normal recovery	N = 59 71.40 (66.38 to 76.42)	N = 61 94.88 (92.41 to 97.34)
	SREF	N = 84 82.49 (78.75 to 86.23)	N = 84 85.81 (81.97 to 89.66)
Physical functioning	SRC delayed recovery	N = 54 53.70 (47.07 to 60.34)*†	N = 53 96.64 (94.66 to 98.62)
	SRC normal recovery	N = 60 70.83 (65.17 to 76.49)*	N = 61 97.13 (95.75 to 98.51)
	SREF	N = 84 57.89 (52.71 to 63.07)*	N = 83 76.77 (72.39 to 81.15)*
Emotional functioning	SRC delayed recovery	N = 54 73.24 (67.05 to 79.44)†	N = 53 96.32 (93.95 to 98.69)
	SRC normal recovery	N = 61 84.51 (80.22 to 88.80)	N = 60 96.83 (95.14 to 98.53)
	SREF	N = 84 79.11 (74.83 to 83.39)	N = 83 86.75 (82.68 to 90.81)
Social functioning	SRC delayed recovery	N = 54 86.57 (82.40 to 90.75)	N = 53 98.40 (96.76 to 100.00)
	SRC normal recovery	N = 61 92.46 (89.99 to 94.93)	N = 61 97.87 (96.42 to 99.32)
	SREF	N = 83 85.36 (82.09 to 88.63)	N = 83 89.76 (86.48 to 93.03)
School functioning (those attending school)‡	SRC delayed recovery	N = 36 46.11 (38.89 to 53.34)*†§	N = 47 90.85 (86.87 to 94.83)
	SRC normal recovery	N = 44 68.64 (62.23 to 75.05)*	N = 57 92.11 (88.91 to 95.30)
	SREF	N = 62 74.03 (69.88 to 78.18)	N = 63 80.87 (76.19 to 85.56)
Overall HRQOL (those attending school)¶	SRC delayed recovery	N = 36 63.98 (58.94 to 69.02)*†§	N = 47 95.46 (93.31 to 97.61)
	SRC normal recovery	N = 44 79.60 (75.50 to 83.69)	N = 56 95.94 (94.25 to 97.64)
	SREF	N = 61 75.68 (72.12 to 79.24)*	N = 62 83.59 (79.86 to 87.32)

Values represent the number of patients followed by the mean score, for which the maximum number of points is 100 (95% CI). Total numbers of patients do not equal 135 for the SRC groups and 96 for the SREF group because not all patients completed PedsQL assessments at their appointments or were attending school.

* A clinically meaningful difference when compared to healthy norms. Note: The normative data and MCIDs, respectively, for the PedsQL 4.0 Generic Core Scale scores, as reported by Varni et al.,³⁶ are as follows: physical, 87.77 and 6.66; emotional, 79.21 and 8.94; social, 84.97 and 8.36; school, 81.31 and 9.12; and overall, 83.91 and 4.36. The normative datum for the PedsQL Cognitive Functioning Scale score, as reported by Varni et al.,³⁹ is 82.08; the MCID is not reported.

† A clinically meaningful worse score compared to the score in SRC patients with a normal recovery.

‡ Limited to those who were injured during the school year.

§ A clinically meaningful worse score compared to the score in SREF patients.

¶ Physical, emotional, social, and school functioning.

mal and exceeded the MCID compared to healthy youths. At the initial assessment, there were no significant differences in emotional HRQOL among SRC patients who experienced a normal recovery and SREF patients; however, SRC patients who experienced delayed recovery demonstrated significantly lower emotional PedsQL scores than SRC patients who had a normal recovery, although this did not exceed the MCID compared to healthy youths. At

clinical recovery, emotional HRQOL remained normal for all SRC and SREF patients; however, emotional PedsQL scores were significantly higher among both SRC groups than in the SREF group. At the initial assessment, SREF patients reported a social HRQOL that was significantly worse than that for SRC patients who experienced a normal recovery; however, the social PedsQL scores across all groups did not exceed the MCID compared to healthy

TABLE 3. Clinical variables associated with initial HRQOL among adolescent patients with SRC

HRQOL Domain	Clinical Predictor	Mean HRQOL (95% CI)	Change in Mean HRQOL in Youths w/ Initial PCSS = 16 vs PCSS = 4
Cognitive functioning*	Initial $\sqrt{\text{PCSS}}$	-6.51 (-8.66 to -4.36)	-13.02
Physical functioning†	Initial $\sqrt{\text{PCSS}}$	-7.13 (-8.78 to -5.48)	-14.26
	Male	12.50 (5.85 to 19.14)	
	Previous concussion	-7.48 (-14.44 to -0.52)	
	ADHD	25.70 (4.57 to 46.82)	
Emotional functioning‡	Initial $\sqrt{\text{PCSS}}$	-3.66 (-6.05 to -1.26)	-7.32
	Male	7.43 (-0.17 to 15.04)	
	Previous concussion	-10.85 (-18.95 to -2.75)	
	Age	-3.29 (-6.45 to -0.13)	
	Adequate school accommodations	11.95 (2.22 to 21.68)	
Social functioning§	Initial $\sqrt{\text{PCSS}}$	-2.38 (-3.32 to -1.44)	-4.76
	Previous concussion	-5.43 (-9.83 to -1.04)	
School functioning	Initial $\sqrt{\text{PCSS}}$	-4.30 (-6.75 to -1.85)	-8.60
	Adequate school accommodations	12.43 (1.82 to 23.04)	
	Delayed recovery	-13.40 (-23.81 to -3.00)	
Overall HRQOL¶	Initial $\sqrt{\text{PCSS}}$	-4.89 (-6.16 to -3.62)	-9.78
	Male	6.65 (1.67 to 11.64)	
	Previous concussion	-8.75 (-14.17 to -3.33)	

$\sqrt{\text{PCSS}}$ = square root of the Post-Concussion Symptom Scale score.

* Adjusted for perceiving school-related accommodations as adequate and developing delayed recovery.

† Adjusted for loss of consciousness and perceiving school-related accommodations as adequate.

‡ Adjusted for loss of consciousness and developing delayed recovery.

§ Adjusted for perceiving school-related accommodations as adequate.

¶ Adjusted for loss of consciousness and perceiving school-related accommodations as adequate.

youths. At clinical recovery, both SRC groups had significant improvement in their social HRQOL when compared to scores at the initial assessment, while SREF patients had a similar social HRQOL at both time points. Last, SRC patients attending school who experienced a normal or delayed recovery reported worse school HRQOL than healthy youths—exceeding the MCID. However, only SRC patients who experienced a delayed recovery demonstrated significantly worse school HRQOL than SREF patients. At clinical recovery, all patients reported normal school HRQOL.

Clinical Variables Associated With Initial HRQOL Among SRC Patients

Table 3 summarizes adjusted associations between the clinical variables and initial HRQOL among SRC patients. A worse initial overall HRQOL was associated with a higher initial PCSS score, a history of previous concussion, and female sex. For all domains of HRQOL, a higher initial PCSS score was associated with a significantly worse HRQOL. Female sex and a history of previous concussion were associated with a worse initial physical HRQOL, while history of ADHD was associated with a better physical HRQOL. History of previous concussion was associated with both worse emotional and social HRQOL. SRC patients who reported that their schools provided adequate accommodations for their injury experienced better emotional and school HRQOL. Experienc-

ing a delayed clinical recovery was also associated with a worse school HRQOL.

Longitudinal Assessment of HRQOL

Adjusted weekly improvements in HRQOL are summarized in Table 4. SRC patients who experienced a normal recovery demonstrated the greatest weekly improvements in overall HRQOL. SRC patients who experienced a delayed recovery and SREF patients experienced similar weekly improvements in HRQOL. For all 5 domains of the HRQOL, the greatest weekly improvements were observed among SRC patients who experienced a normal recovery, and the weekly gains were significantly higher for cognitive, physical, emotional, and school functioning than those observed among SRC patients with delayed recovery and SREF patients. Weekly improvements in social functioning were similar for all patients.

Physician-Documented Clinical Recovery

Overall, 132 (97.8%) of the SRC patients and all of the SREF patients attained physician-documented clinical recovery during the study period. The median number of days until physician-documented clinical recovery for the SRC patients was 26 days (IQR 17–49 days), and this was not significantly different from the number of days for the SREF patients (31 days; IQR 23–42 days; $p = 0.12$). SRC patients who experienced a normal recovery did so significantly faster than SREF patients (Table 5).

TABLE 4. Weekly improvements in HRQOL for adolescent patients with SRC or SREF

HRQOL Domain	Injury Status (no. of patients)	Mean HRQOL (95% CI)
Cognitive functioning	SRC normal recovery (N = 44)	10.92 (7.47 to 14.37)*
	SRC delayed recovery (N = 48)	3.66 (2.59 to 4.72)*
	SREF (N = 96)	0.89 (0.31 to 1.48)
Physical functioning	SRC normal recovery (N = 62)	13.40 (9.95 to 16.85)†
	SRC delayed recovery (N = 48)	4.86 (3.50 to 6.23)†
	SREF (N = 96)	4.36 (3.47 to 5.25)
Emotional functioning	SRC normal recovery (N = 62)	6.62 (4.39 to 8.85)‡
	SRC delayed recovery (N = 48)	3.05 (2.09 to 4.01)‡
	SREF (N = 96)	1.96 (1.28 to 2.64)
Social functioning	SRC normal recovery (N = 44)	1.95 (0.40 to 3.50)*
	SRC delayed recovery (N = 48)	1.25 (0.70 to 1.80)*
	SREF (N = 96)	0.92 (0.41 to 1.42)
School functioning	SRC normal recovery (N = 58)	11.19 (8.24 to 14.13)
	SRC delayed recovery (N = 47)	5.12 (3.95 to 6.29)
	SREF (N = 76)	2.07 (1.39 to 2.75)
Overall HRQOL	SRC normal recovery (N = 58)	7.83 (5.96 to 9.70)
	SRC delayed recovery (N = 47)	4.02 (3.13 to 4.90)
	SREF (N = 76)	2.55 (1.93 to 3.17)

* Adjusted for perceiving school-related accommodations as adequate.

† Adjusted for loss of consciousness at injury and perceiving school-related accommodations as adequate.

‡ Adjusted for loss of consciousness at injury.

Discussion

The purpose of this study was to compare the effects of acute SRC and SREF on HRQOL in adolescents throughout clinical recovery and to identify the clinical variables associated with worse HRQOL among SRC patients.

At the initial assessment, approximately 1 week postinjury, adolescent SRC patients demonstrated clinically meaningful impairments in physical, school, and overall HRQOL and worse cognitive HRQOL compared to healthy adolescents. Adolescents who sustained an SRC reported significantly worse cognitive HRQOL and clinically meaningful impairments in school and overall HRQOL compared to those who sustained an SREF. The initial PedsQL Generic Core Scale scores were substantially worse than those observed in a previous study of adolescent SRC patients evaluated at 3 days postinjury.¹³ The initial cognitive functioning scores were also worse than scores reported in previous studies of pediatric patients with mild TBI (mTBI) who had been evaluated 1 month postinjury³⁰ and patients with TBI (Abbreviated Injury Scale scores 0–4) who had been evaluated at 3 and 12 months postinjury.²² Similar to our previous study,³⁴ we found that the magnitude of HRQOL impairments observed among SRC patients at the initial assessment predicted the length of physician-documented clinical recovery. SRC patients who experienced delayed recovery reported significantly worse initial cognitive functioning HRQOL compared to SRC patients who had a normal recovery and SREF patients. SRC patients who experienced delayed recovery reported initial impair-

TABLE 5. Number of clinic visits and days to both initial assessment and clinical recovery

Factor	Patients	Median No. (IQR)	p Values*
No. of appointments	All SRC patients	3 (3 to 5)	<0.0001
	Delayed recovery	5 (4 to 6)	<0.0001
	Normal recovery	2 (2 to 3)	0.6164
	SREF patients	2 (2 to 3)	—
Days to initial assessment	All SRC patients	6 (5 to 10)	0.0107
	Delayed recovery	8 (5 to 13)	0.4056
	Normal recovery	6 (4 to 8)	<0.0001
	SREF patients	8 (7 to 10)	—
Days to physician-documented clinical recovery	All SRC patients	26 (17 to 49)	0.1189
	Delayed recovery	51 (34 to 83)	<0.0001
	Normal recovery	17 (13 to 23)	<0.0001
	SREF patients	31 (23 to 42)	—

* In comparison with SREF patients.

ments in school and overall HRQOL that exceeded the MCID compared to healthy adolescents, SRC patients who experienced a normal recovery, and SREF patients.

Initial HRQOL scores were also affected by clinical variables that have been identified as important clinical predictors of outcome following concussion. Initial symptom burden has been identified as the strongest predictor of delayed recovery, whereas research supporting age, sex, and preinjury history of previous concussion and ADHD as important clinical predictors remains mixed.¹⁵ In this study, the initial PCSS score was associated with worse results on all PedsQL scores. This is consistent with previous studies' findings of a strong relationship between initial symptom burden and HRQOL.^{13,26,34} In addition, a history of previous concussion was associated with worse physical, emotional, social, and overall HRQOL. Importantly, school HRQOL was also impacted by whether or not SRC patients perceived their school to have provided adequate accommodations during their recovery. Taken together, the results of this study suggest that adolescent SRC is associated with impairments in overall, physical, school, and cognitive HRQOL, and that SRC patients experience greater impairments in cognitive, school, and overall HRQOL than SREF patients. Initial HRQOL is affected by multiple demographic and clinical factors, most notably a history of previous concussion, length of clinical recovery, and the initial symptom burden.

In this study, we compared changes in HRQOL throughout the clinical recovery process and again at the time of medical clearance. To date, few studies have focused on longitudinal HRQOL among pediatric concussion and mTBI patients;¹² thus, it remains unclear whether HRQOL impairments experienced at the time of the initial injury resolve over time or persist beyond symptomatic recovery. Pieper and Garvan³⁰ evaluated child- and parent-reported HRQOL among children with mTBI, children with non-TBI injuries, and uninjured children at baseline and 1, 3, 6, and 12 months postinjury. Those researchers found that pediatric mTBI patients had similar pre- and postinjury

HRQOL, with PedsQL total and subscale score differences that were less than the MCID. Houston et al.¹³ examined HRQOL among adolescent SRC patients at baseline and 3 and 10 days postinjury. Although clinically meaningful impairment in physical HRQOL was observed at 4 days postinjury compared to baseline measurements, all PedsQL scores were normal and within the MCID at day 10 postinjury, compared to baseline. In contrast, a multi-institutional study of pediatric patients who underwent longitudinal assessment of postconcussion symptoms and HRQOL at 4, 8, and 12 weeks postinjury through telephone or Web-based surveys found that patients who reported worsening of 3 or more postconcussion symptoms compared to baseline (PPCS) demonstrated worse overall, physical, emotional, social, and school HRQOL at 4 weeks postinjury compared to those who did not meet this criterion.²⁷ At 4 weeks postinjury, pediatric concussion patients without PPCS demonstrated normal physical, emotional, and social HRQOL, but impaired overall HRQOL primarily due to an impaired school HRQOL. At 12 weeks postinjury, overall HRQOL among patients without PPCS had returned to normal, but school HRQOL remained impaired compared to healthy norms. We found that HRQOL improved over time in both SRC and SREF patients, with greater weekly improvements observed among SRC patients who experienced a normal versus delayed recovery and SREF patients. Importantly, we found no evidence of persistent impairments in HRQOL among adolescent SRC patients who were followed up to physician-documented clinical recovery. This is consistent with our previous longitudinal study of HRQOL among adolescent SRC patients³⁴ and a more recent study that demonstrated no persistent impairments in HRQOL or psychological functioning among adolescents with a history of one or multiple concussions compared to those with an orthopedic injury.³¹

Our results have potentially important implications for the clinical management of acute pediatric SRC patients. Although most pediatric SRC patients will attain neurological recovery within 1–4 weeks, an important proportion will experience persistent symptoms that contribute to delayed clinical recovery.³ The results of this study suggest that initial management of adolescent acute SRC patients should focus on early interventions that help optimize physical, cognitive, and school functioning. Accumulating research suggests that physical symptoms of acute concussion, including headaches, dizziness, and blurred vision, can arise as a consequence of exercise intolerance and vestibulo-ocular and cervical spine dysfunction that often resolve spontaneously but may require targeted rehabilitation.^{9,11,18} Our finding that adequate school accommodations were associated with improved school HRQOL in SRC patients provides support for providing SRC patients with return-to-learn programs that allow students to make a gradual return to school and help minimize cognitive-related symptoms.^{20,32,33} Future studies are needed to address the added clinical value of incorporating patient-reported HRQOL outcome measures into the standardized management of patients with acute concussion and PCSS.

Limitations of the Study

This study has important limitations. First, we included

patients who were evaluated at pediatric subspecialty clinics. Due to the referral bias, this study likely included SRC patients with more severe injuries—more likely to experience delayed recovery and potentially greater impairments in HRQOL—than a more generalized sample of patients who are evaluated in emergency departments or primary care facilities. Second, we only included patient self-reported measures of HRQOL and did not include parent-reported outcomes. Previous research suggests that children and parents can differ in their perceptions of the impact of medical conditions on patient HRQOL, especially with respect to emotional and social HRQOL.⁸ While few studies have focused on the concordance between patient and parental proxy measures of HRQOL in concussion and mTBI,²⁹ it is well known that children and adolescents continue to demonstrate deficiencies in concussion awareness and can underreport symptoms.^{2,16} In future studies, researchers should consider including both patient- and parent-reported measures to understand the differential effects of SRC and SREF on HRQOL. Third, HRQOL was assessed using only the PedsQL Generic Core Scale and Cognitive Functioning Scale. Although these instruments provide a valid and reliable assessment of HRQOL in pediatric patients with a wide spectrum of acute and chronic medical conditions, including TBI,^{22,36,40} they may not capture aspects of postinjury functioning and HRQOL that are more relevant to pediatric TBI patients.⁵ Therefore, future studies may benefit from the development of validated disease-specific HRQOL instruments for pediatric concussion patients and incorporate semistructured interviews that assess for the more subtle consequences of this injury. Fourth, other authors have found that HRQOL following pediatric TBI can be affected by important non-injury factors, including baseline HRQOL and socioeconomic status.^{26,41} School-related HRQOL could also be affected by baseline school performance and functioning. These factors were not assessed in the present study and should be considered in future studies. Fifth, certain clinical features of acute SRC, such as exercise intolerance, vestibulo-ocular dysfunction, and cervical spine dysfunction, are important contributors to symptom burden and delayed recovery,^{9,11,18} however, data on these variables were not collected in this study. Future research should evaluate the effect of these clinical features on HRQOL following SRC and assess whether rehabilitation strategies targeting the pathophysiological processes responsible for persistent symptoms improve HRQOL. Sixth, SRC patients were slightly older and underwent the initial assessment a median of 2 days sooner after injury than SREF patients. The SRC cohort included patients with a higher prevalence of previous concussion compared to the SREF cohort. Finally, SRC patients may have been motivated to underreport their symptoms or rate their HRQOL as more favorable in order to avoid missing time away from sports and other activities. These important factors should also be considered when interpreting the results of this study.

Conclusions

Acute SRC in adolescents is associated with initial impairments in overall, physical, school, and cognitive

HRQOL. Compared to SREF, adolescent SRC patients experience significantly greater impairments in cognitive, school, and overall HRQOL. The degree of impairment experienced by adolescent SRC patients across HRQOL domains is affected by previous concussion, initial symptom burden, and length of clinical recovery. Despite these findings, no persistent impairments in HRQOL were observed among SRC patients who were followed to physician-documented clinical recovery. Future studies investigating the role of active rehabilitation strategies in acute SRC should include measures of HRQOL.

Acknowledgments

Dr. Russell received an Establishment Grant from The Manitoba Health Research Council (now Research Manitoba) and this funding was used to support this study; however, the funders played no role in data collection or interpretation of the results.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Russell, Ellis. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: Russell, Ellis. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Russell. Statistical analysis: Russell.

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