Effect of concussion history on symptom burden and recovery following pediatric sports-related concussion

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OBJECTIVE The aim of this study was to examine differences in symptom burden and duration until physician-documented clinical recovery among pediatric patients with sports-related concussion (SRC) with and without a history of concussion.

METHODS A retrospective chart review was performed for all pediatric patients (7–19 years old) referred to the Pan Am Concussion Program in Winnipeg, Canada, with an SRC and evaluated < 30 days postinjury between September 1, 2013, and August 1, 2015.

RESULTS A total of 322 patients with SRC (64.91% male, mean age 13.96 years) who were evaluated a median of 7 days (interquartile range [IQR] 5–11 days) postinjury were included. Patients without a history of concussion endorsed significantly fewer concussion symptoms at initial assessment (median 5.5 symptoms, IQR 1–10 symptoms) than those with a previous concussion (median 7 symptoms, IQR 2–13.25 symptoms; p = 0.036). The median Post-Concussion Symptom Scale scores were 9 (IQR 1–23) for patients with no concussion history and 13 (IQR 3–33) for those with a history of concussion (p = 0.032). For patients with no previous concussion, the median number of days until physician-documented clinical recovery was 23 (IQR 15–44 days) compared with 25 days (IQR 18–43 days) for those with a history of concussion (p = 0.281). There was no significant difference in the proportion of patients who experienced delayed time until physician-documented clinical recovery (> 1 month postinjury) between the groups (p = 0.584).

CONCLUSIONS Although a history of concussion may be associated with increased symptom burden following pediatric SRC, there was no difference in the time until physician-documented clinical recovery. Pediatric patients with SRC who have a history of concussion should be managed on an individualized basis. Future work is needed to examine the short- and long-term effects of multiple concussions in children and adolescents.

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KEY WORDS sports-related concussion; concussion history; pediatric; symptoms; predictors; recovery; outcomes; trauma
comes of patients with SRC is a history of concussion. Preliminary neuroimaging studies suggest that concussion is associated with alterations in white matter integrity, brain activation, and cerebrovascular physiology that may persist beyond symptomatic recovery and may confer an increased vulnerability to repeat trauma.20 Without a complete understanding of the effect of concussion history on pediatric SRC outcomes, multidisciplinary management (including return-to-play and sport retirement decision making in patients with multiple concussions) remains challenging.3,7,13

Although previous studies have generated mixed results regarding the effect of concussion history on initial symptom burden and duration of symptoms following concussion,19 few studies have examined these relationships within a cohort of pediatric patients with SRC followed to physician-documented clinical recovery and controlled for other important modifiers of recovery.19,26,40

To address this knowledge gap, we conducted a retrospective chart review of pediatric patients with SRC presenting to a multidisciplinary pediatric concussion program within 30 days of injury. We examined differences in symptom burden at initial presentation and time until physician-documented clinical recovery among patients with and without a history of concussion.

Methods

Study Design and Setting

A retrospective chart review was performed for pediatric patients with SRC who were referred to the Pan Am Concussion Program in Winnipeg, Manitoba, Canada, between September 1, 2013, and August 1, 2015. The Pan Am Concussion Program is the only multidisciplinary pediatric concussion program in Manitoba and receives referrals from local emergency departments, pediatricians, and family medicine and sports medicine physicians. The institutional ethics review board at the University of Manitoba approved this study.

Study Participants

Inclusion criteria for the study included the following: 1) patients 7–19 years of age; 2) physician-diagnosed SRC; and 3) initial clinical assessment < 30 days from the date of injury. Patients were excluded if they 1) demonstrated traumatic abnormalities on neuroimaging (that is, intracranial hemorrhage); 2) suffered a second head injury during follow-up; or 3) were diagnosed with a coexistent spinal injury or neurological condition that affected clinical recovery (e.g., cranial neuropathy, spinal cord injury).

Clinical Assessment and Definitions

Upon initial presentation to the pediatric concussion program, each patient completed a standardized data collection form that included demographic information, sport played at the time of concussion, medical history, past family history, and concussion history. All patients also completed the Post-Concussion Symptom Scale (PCSS), a reliable and valid measure of symptom burden following concussion.3,25

All patients underwent initial clinical history and phys-
propriate). In general, patients were considered neurologically recovered when they were free of symptoms at rest according to clinical interview, had a normal neurological examination, and were tolerating full school activities and exercise without symptoms. Patients with preexisting conditions, such as migraine, depression, or attention-deficit hyperactivity disorder, were considered recovered when they had returned to their neurological baseline at rest and during school and exercise.

In select cases, confirmation of neurological recovery was supplemented with the use of graded aerobic treadmill testing and neuropsychological testing at the discretion of the neurosurgeon. In-season athletes were also managed according to the graduated return-to-play protocol set forth by the 4th Concussion In Sport Group consensus statement.²⁹ Because of a lack of empirical evidence to support routine use of postinjury computerized neurocognitive testing in pediatric patients with SRC, these tests are only used on a selective basis at our institution.

Given that the vast majority of pediatric patients with SRC recover within 1 month postinjury,²⁸ we defined delayed time until physician-documented clinical recovery as a patient who achieved physician-documented clinical recovery > 1 month (30 days) from the date of injury.

Statistical Analysis

The distributions of baseline characteristics were described for patients with and without a history of concussion. If a continuous variable was not normally distributed, it was reported as the median with interquartile ranges (IQRs); normally distributed data were reported as the mean with a standard deviation. Dichotomous/polytomous clinical characteristics for the groups were compared using a chi-square test. Continuous, normally distributed clinical characteristics were compared using the unpaired t-test. If continuous data were not normally distributed, statistical significance was assessed using the rank-sum test. The Kruskal-Wallis test was used to compare patients with no, 1, or ≥ 2 previous concussions for the 4 outcomes of interest.

Ordinal logistic regression was conducted and time until physician-documented clinical recovery was collapsed into 4 groups to reflect different trajectories of recovery: 0–14, 15–29, 30–89, and ≥ 90 days. Backward elimination was undertaken. First, effect modification was examined by including interaction terms for concussion history and number of symptoms at initial assessment, where number of symptoms was divided into quartiles (0–1, 2–5, 6–11, or ≥ 12 symptoms). Vestibulo-ocular dysfunction was not included as a potential confounder because it includes several of the concussion symptoms included in the PCSS (e.g., dizziness, difficulty concentrating).¹¹ For the initial PCSS score, the outcome was categorized based on quartiles (0–1, 2–9, 10–29, and ≥ 30) and included the same assessment of interaction terms and potential confounders as the number of symptoms at presentation analysis. For all statistical tests, a 2-sided p value < 0.05 was interpreted as statistically significant.

Results

Baseline Characteristics

A total of 322 participants were included. Overall, patients were evaluated a median of 7 days (IQR 5–11 days) from the time of injury. Patients with no concussion history (n = 199) were evaluated a median of 7 days (IQR 5–11 days) postinjury, and those with a history of concussion (n = 123) were evaluated a median of 8 days (IQR 5–14 days) postinjury (p = 0.18). The median number of concussions among patients who reported a history of concussions was 1 (IQR 1–2 concussions), with 76 (61.8%) having sustained 1 previous concussion, and 47 (38.2%) having sustained ≥ 2 previous concussions. Table 1 describes demographic characteristics and symptoms reported at initial consultation, as well as the sport or activity in which the injury occurred.

Number of Symptoms at Initial Assessment

Patients with no history of concussion reported a statistically significantly lower median number of symptoms (5.5 symptoms, IQR 1–10 symptoms) at initial assessment than those who had a history of concussion (7 symptoms, IQR 2–13.25 symptoms; p = 0.036). When the number of symptoms was categorized, there was a significant unadjusted association between concussion history and number of symptoms (OR 1.59, 95% CI 1.06–2.40). Multivariate ordinal logistic regression revealed that sex (p = 0.65), age (p = 0.37), and days until initial assessment (p = 0.95) did not modify the association. Only age confounded the association, and this attenuated the association between concussion history and number of symptoms at initial assessment (OR 1.24, 95% CI 0.81–1.93). The Brant test showed that the parallel regression assumption was not violated (p = 0.47), indicating that the symptom intervals chosen for analysis were appropriate.
There was a significant difference in the median PCSS score at initial assessment among patients with a history of concussion (PCSS score 13, IQR 3–33) compared with those with no previous concussion (PCSS score 9, IQR 1–23; p = 0.032). After categorizing at quartiles, the unadjusted odds ratio was 1.59 (95% CI 1.05–2.39). There was no evidence of effect modification by sex (p = 0.50), age (p = 0.52), or days until initial assessment (p = 0.66). This relationship was no longer significant after adjusting for the confounding effects of age (OR 1.21, 95% CI 0.78–1.87). The parallel regression assumption was met (p = 0.47), indicating that the PCSS quartiles were appropriate.

### Time Until Physician-Documented Clinical Recovery

For the pediatric patients with SRC with no history of concussion, the median time until physician-documented clinical recovery was 23 days (IQR 15–44 days) compared with 25 days (IQR 18–43 days) among those with a history of concussion (p = 0.281) (Table 2). The unadjusted odds ratio between length of recovery and concussion history was 1.27 (95% CI 0.83–1.93). There was no evidence of effect modification by sex (p = 0.40) or days until initial assessment (p = 0.60), but there was effect modification by age (p = 0.006). After controlling for confounders, age modified the association between a history of concussion and time until physician-documented clinical recovery (Table 3). The parallel regression assumption was not violated (p = 0.27), indicating that the clinical categorization of length of recovery chosen for analysis was appropriate.

### Delayed Time Until Physician-Documented Clinical Recovery

There was no significant association between the unadjusted odds of experiencing delayed time until physician-documented clinical recovery and concussion history (OR 1.14, 95% CI 0.72–1.79). There was also no evidence of effect modification by sex (p = 0.34) or days to initial assessment (p = 0.21), but age did modify the association (p = 0.003). After adjusting for confounders, age modified the association between history of concussion and development of delayed time until physician-documented clinical recovery (Table 3). There was no difference in the unadjusted odds of experiencing delayed time until physician-documented clinical recovery among those with 1 (OR 1.01, 95% CI 0.59–1.74) or ≥2 previous concussions (OR 1.37, 95% CI 0.72–2.59) compared with no history of concussion.

### Sensitivity Analysis on Loss to Follow-Up

Forty-four patients (13.7%) were lost to follow-up during the study period, and they were significantly more likely to have had a history of concussion (p = 0.016). They were also significantly older (p < 0.0001) and female (p = 0.0001), had a higher initial PCSS score (p = 0.0001), and presented with more symptoms (p < 0.0001) than those who achieved physician-documented clinical recovery. The number of days between initial clinical assessment and date of last appointment was calculated to determine if date of last follow-up was associated with history of concussion. Among patients lost to follow-up, there was no significant difference in days until last follow-up and concussion history (no history of concussion 46 days [IQR 10–116 days] vs 41 days [IQR 16–82 days] for those with a history of concussion; p = 0.954).

The role of having no, 1, or ≥2 previous concussions on the 4 outcomes was examined. There was no signifi-
cant association between concussion history and delayed time until physician-documented clinical recovery (p = 0.98), time until physician-documented clinical recovery (p = 0.73), number of symptoms (p = 0.42), or initial PCSS score (p = 0.41).

Discussion

This study provides important insight into the independent modifying effect of concussion history on initial symptom burden and clinical recovery in pediatric patients with SRC. In this cohort of patients (evaluated at a multidisciplinary pediatric concussion program a median of 7 days postinjury), we found that patients with a history of concussion endorsed a greater number of symptoms and had higher PCSS scores at initial assessment than patients without a previous concussion. Although these findings may suggest that patients with a history of concussion are at an elevated risk of sustaining more severe injuries, the number and magnitude of concussion symptoms reported by pediatric patients with SRC are probably affected by a variety of preinjury and postinjury factors.

Previous studies have suggested that athletes with a history of concussion are at an elevated risk of sustaining another concussion during the same season and that those with a history of 1 or multiple concussions may be at an elevated risk of sustaining future concussions that manifest with more severe signs of injury (e.g., loss of consciousness, postrauumatic amnesia, or confusion). Although measures of symptom burden were found to be higher among patients with a previous concussion in this study, the number of symptoms between the groups varied by only 1 symptom. In addition, we did not observe any group differences in time until physician-documented clinical recovery or the risk of experiencing delayed time until physician-documented clinical recovery in this study. However, age did significantly modify this association such that younger patients with a history of concussion experienced significantly longer recovery times, whereas older patients with a history of concussion experienced significantly shorter recovery times, even after controlling for other potential variables.

Overall, the relationship among age, a history of concussion, and short-term outcomes (e.g., length of recovery) remains unclear. In a recent systematic review of predic-

| TABLE 2. Clinical outcomes of pediatric patients with SRC with and without a history of concussion |
|-----------------------------------------------|-----------------|-----------------|-------|
| Outcome                                      | No Concussion History | History of Concussion | p Value |
| No. of patients                              | 199          | 123             |       |
| Median no. of symptoms at initial assessment (IQR) | 5.5 (1–10)  | 7 (2–13.25)   | 0.036 |
| Median PCSS score at initial assessment (IQR)  | 9 (1–23)     | 13 (3–33)      | 0.032 |
| Achieved physician-documented clinical recovery, no. (%) | 177 (88.9)  | 98 (79.7)      | 0.022 |
| Median no. days until physician-documented clinical recovery (IQR) | 23 (15–44) | 25 (18–43)    | 0.281 |
| Experienced delayed time until physician-documented clinical recovery, no. (%) | 78 (39.2)   | 52 (42.3)      | 0.584 |

| TABLE 3. Age-specific estimates of concussion history and time until physician-documented clinical recovery |
|-----------------------------------------------|-----------------|-----------------|-------|
| Patient Age in Yrs                           | Time Until Physician-Documented Clinical Recovery* | Experienced Delayed Time Until Physician-Documented Clinical Recovery† |
| 8                                            | 7.4 (1.4–37.9) | 15.9 (1.8–137.6) |
| 9                                            | 5.2 (1.3–21.3) | 9.6 (1.5–61.5)  |
| 10                                           | 3.7 (1.1–12.0) | 5.9 (1.2–27.7)  |
| 11                                           | 2.6 (0.9–6.8)  | 3.6 (1.0–12.6)  |
| 12                                           | 1.8 (0.8–3.9)  | 2.2 (0.8–5.9)   |
| 13                                           | 1.3 (0.7–2.4)  | 1.3 (0.6–2.9)   |
| 14                                           | 0.9 (0.5–1.5)  | 0.8 (0.4–1.6)   |
| 15                                           | 0.6 (0.8–11)   | 0.5 (0.2–1.0)   |
| 16                                           | 0.4 (0.2–0.9)  | 0.3 (0.1–0.7)   |
| 17                                           | 0.3 (0.1–0.7)  | 0.2 (0.1–0.5)   |
| 18                                           | 0.2 (0.1–0.6)  | 0.1 (0.03–0.4)  |
| 19                                           | 0.2 (0.5–05)   | 0.1 (0.01–0.4)  |

Values reported as odds ratio (95% CI).
* Adjusted for loss of consciousness, amnesia, vestibulo-ocular dysfunction at initial clinical assessment, number of symptoms at initial clinical assessment, and number of days between concussion and initial clinical assessment.
† Adjusted for loss of consciousness, vestibulo-ocular dysfunction at initial clinical assessment, number of symptoms at initial clinical assessment, history of migraines or nonspecific headaches, history of depression, and number of days between concussion and initial clinical assessment.
tors of persistent symptoms following pediatric concussi
Zemek et al. found that many of the included stud-
ies excluded patients with previous head injuries. Among
available studies, Ponsford et al. conducted a prospective
case-control study of mild traumatic brain injury (TBI) and
injured control subjects. They found evidence of per-
sistent symptoms and behavioral problems in 17% of pa-
tients with mild TBI at 3 months postinjury that were more
common among those with a history of head injury, learn-
ing difficulties, and premorbid stressors.

Similarly, Eisenberg et al. found that pediatric patients
with concussion who had a history of concussions expe-
ranced a longer duration of self-reported symptoms than
those without a previous concussion (24 vs 12 days). In ad-
dition, they found that those with a history of multiple con-
cussions experienced a longer duration of symptoms (28
days), especially if they had sustained a concussion in the
previous year (35 days). Although the findings of these 2
studies suggest a potential cumulative effect of concussion
in children and adolescents, other studies of patients with
concussion evaluated in the emergency room and tertiary
concussion clinic settings have demonstrated mixed results
regarding the independent effect of previous concussion
on patient outcomes. As such, additional work is needed
to evaluate the effect of concussion history on patient out-
comes across different age groups.

Despite the increased academic attention that is focused
on the effects of concussion in children and adolescents,
the clinical management of pediatric patients with SRC
who have sustained multiple concussions remains chal-
 lenging. Accumulating preliminary evidence suggests that
lifetime history of concussion and subclinical repetitive
head injury may place some athletes at an elevated long-
term risk of depression, neurocognitive impairment, and
neurodegenerative diseases, such as chronic traumatic en-
cephalopathy. At present, however, there are no evi-
dence-based clinical guidelines to direct return-to-sport
and retirement from sport decision making in patients who
present with multiple concussions. As a consequence, clin-
cal recommendations should be made on an individual pa-
tient basis by a multidisciplinary team of TBI experts who
place the highest value on the patient’s short- and long-
term health.

This study has several important limitations. First, it
was conducted at a tertiary concussion program that may
have included patients with more severe injuries, patients
who were more likely to have a history of concussion, and
those who were more likely to experience delayed clinical
recovery.

Second, patients underwent initial clinical assessment
at our multidisciplinary concussion program a median of
7 days postinjury, which probably affected the burden of
initial concussion symptoms observed in this population.
Therefore, these results are probably generalizable to pa-
tients who present to tertiary concussion clinics at different
subacute stages of injury but not to those who present more
cutely in the emergency room or other ambulatory care
settings.

Third, although recent research suggests that high
school athletes can provide a reliable report of previous con-
cussions, concussion history in this study was based
solely on patient and parental report and thus may not be
an accurate reflection of true concussion history. Despite
the increased attention focused on concussion, youth ath-
letes continue to demonstrate deficiencies in concussion
awareness and underreport these injuries. Information
about the temporal relationship between the patient’s
previous concussion(s) and current concussion was also not
available for all patients and thus was not analyzed in this
study.

Fourth, although patients with a history of concussion in
this study endorsed a higher number of concussion symp-
toms and exhibited higher PCSS scores at initial presen-
tation following SRC, baseline concussion symptom data
were not available. As mentioned, patients with a history of
concussion have been found to endorse more symptoms at
baseline. This may have accounted for some of the dif-
f erences in initial symptom burden observed in this study.

Fifth, a number of additional variables have been found
to affect postinjury symptom reporting and length of re-
covery following concussion and mild TBI; these factors
include resilience, somatization, and social and family
functioning. There may be other potential confounders
that were not assessed in this study, such as severity of pre-
vious concussion(s). These variables were not measured
in this study and should be considered in future studies.

Sixth, a small proportion of patients in this study were
lost to follow-up. This limitation remains a challenge for
tertiary concussion clinics and may have affected the study
results. Our sensitivity analysis demonstrated that patients
lost to follow-up were more likely to have a previous con-
cussion, report more symptoms, and present with higher
initial PCSS scores at initial clinical assessment compared
with those who achieved physician-documented clinical
recovery during the study period.

Seventh, the criteria used to confirm clinical recovery in
this study did not allow for a standardized follow-up regi-
men (that is, daily assessments). As such, the date on which
clinical recovery was documented by the physician may
have been affected by patient sports schedules and other
factors. However, this limitation is offset by using criteria
that more closely reflect clinical milestones that must be
achieved to confirm complete recovery in youth athletes
compared with relying on self-reported resolution of con-
cussion symptoms alone.

Last, this study only examined the effects of previous con-
cussion on short-term outcomes. To help inform the
evidence-based, individualized management of pediatric
patients with SRC, future population-based and prospec-
tive clinical studies are needed to elucidate the effects of
concussion(s) on long-term health and cognitive and psy-
chological functioning.

Conclusions

Despite these limitations, the present study suggests
that overall, pediatric patients with SRC with a history of
concussion may report a greater burden of symptoms at
initial presentation than those without a history of concus-
sion, but do not experience a longer length of time until
physician-documented clinical recovery. However, the ef-
fect of concussion history on clinical recovery seems to be
strongly affected by patient age. These results suggest that

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pediatric patients with SRC should be managed on an individualized basis, taking into account the unique pre- and postinjury factors that mediate clinical symptoms and recovery. Future studies are needed to evaluate the effect of concussion and repetitive head injury on short- and long-term outcomes in children and adolescents.

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References

33. Nelson LD, Tarima S, LaRoche AA, Hammek TA, Barr

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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: Russell, Ellis. 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.

Supplemental Information
Previous Presentations
Portions of this study were previously presented in abstract form at the 5th International Consensus Conference on Concussion in Sport, Berlin, Germany, October 27–28, 2016, and the University Health Network Traumatic Brain Injury Conference, Toronto, Ontario, Canada, February 10, 2017. An early abstract was also published as “Presenting Symptoms and Recovery Time Among Youth Athletes With and Without a History of Concussion” in the *British Journal of Sports Medicine* **15**:A19, 2017.

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