BMJ Open Sport & Exercise Medicine

Association of early versus late care seeking for sport-related concussion in adolescent athletes in Canada: a historical cohort study

David Youngwoo Oh ,[1] Darrin Germann,[1] Carolina Cancelliere,[2] Mohsen Kazemi,[1] Cameron Marshall,[3] Sheilah Hogg-Johnson[4,5]

To cite: Oh DY, Germann D, Cancelliere C, *et al*. Association of early versus late care seeking for sport-related concussion in adolescent athletes in Canada: a historical cohort study. *BMJ Open Sport & Exercise Medicine* 2025;**11**:e002241. doi:10.1136/bmjsem-2024-002241

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjsem-2024-002241).

Accepted 11 December 2024

For numbered affiliations see end of article.

Correspondence to
Dr David Youngwoo Oh; davidywoh@gmail.com

ABSTRACT

Objectives This study aims to examine the association of time to recovery between early versus late presentation to outpatient community-based concussion management clinics following sport-related concussion (SRC) among adolescent Canadian athletes.

Methods Using electronic health records (between January 2017 and December 2019) from the Complete Concussion Management Inc (CCMI) database, this was a historical cohort study of Canadian athletes aged 12–18 presenting for care early (0–7 days) or late (8–28 days) after SRC. Time-to-recovery was defined as the date of clinician clearance to return to sport. Propensity scores were first derived from logistic regression with early versus late clinical presentation as the outcome. Cox proportional hazards regression analysis was then used to model the relationship between early versus late clinical presentation and time to recovery, while including the propensity score to adjust for confounding. The association was expressed using hazard rate ratios (HRR) with 95% CIs.

Results A total of 4696 patient records (mean age of 14.71 (±1.69 SD); 57.7% male) were eligible. Early presentation to a concussion management clinic following SRC was associated with faster time to recovery (adjusted HRR 1.23; 95% CI 1.14 to 1.32, p<0.001). This association was consistent within each quintile of the propensity score. The median time to recovery was 18 versus 22 days in the early and late groups, respectively.

Conclusion Adolescent athletes with SRC have favourable recovery trajectories when presenting for care up to 28 days. Time to recovery (clinician clearance to return to sport) may be quicker with an earlier presentation which can lead to a faster return to sport.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Earlier care for sport-related concussions in adolescents is believed to lead to faster recovery, but previous studies often had methodological flaws such as immortal time bias and inadequate confounding control. These limitations created uncertainty about the true impact of early intervention, making further investigation necessary.

WHAT THIS STUDY ADDS

⇒ This study provides evidence that early care (within 0–7 days) after a concussion results in faster recovery for adolescent athletes compared with late care (8–28 days). Using propensity score adjustments, it minimises confounding factors and highlights the critical role of timely intervention in improving recovery outcomes.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings suggest that healthcare providers should prioritise early assessment for concussions to enhance recovery times. This could lead to updated clinical protocols and policies that encourage rapid access to specialised concussion care, along with educational initiatives to promote early care-seeking behaviour among athletes and their support networks.

INTRODUCTION

Sport-related concussion (SRC) is common in young athletes.[1–3] The incidence of SRC in adolescent athletes was reported as 0.23/1000 athlete exposures (one game or practice) across 12 sports.[2] Another study reported that nearly 20% of adolescents (13 088 respondents) in the USA had experienced one SRC in their lifetime.[3] Furthermore, data across US emergency departments reported the sharpest increase in the number of diagnosed concussions in those aged 5–24 from 1997 to 2019[4]. Although awareness, education and training on SRC are more accessible to all stakeholders, these numbers are still believed to be underestimated.[2 5] Therefore, timely recognition and management of adolescents with SRC are important as symptoms can impair an athlete's emotional and physical well-being, potentially leading to difficulties in school, relationships and sport-related activities.[5–7]

Current guidelines have reported that most adolescents with SRC recover within 4 weeks.[5–7] These guidelines outline a

stepwise plan for the recognition, diagnosis and management, including return to school and sport following SRC.[6 7] However, recent observational studies have challenged the timeline for recovery by suggesting expedited outcomes in individuals who present earlier for care.[8–12] For instance, studies with adolescent athletes who were exposed to earlier symptom-limited exercise following SRC reported more favourable recovery times.[8 9] Similarly, a recent randomised controlled trial reported that adolescents who adhered to symptom-limited aerobic exercise had fewer or reduced symptoms compared with a resting group.[10] This research[8–10] has also led others to investigate the potential effect of time to clinical presentation following SRC and its implications on recovery.

One systematic review on this topic from Barnhart *et al* (2021)[11] reported that earlier presentation to a 'concussion speciality clinic', or clinics that manage concussion regularly, following SRC led to earlier recovery. One study in the review reported that every week of delayed care seeking resulted in a 15% longer recovery from SRC.[12] One additional study reported that patients presenting early demonstrated significantly fewer days until recovery (37±0.2 vs 45.1±0.3 days). This relationship was also reported in another study that showed the late presentation group had a significantly higher OR of a delayed recovery (>30 days) (OR) 9.8, 95% CI 3.3 to 29.0[13] compared with those who presented early.

Unfortunately, studies examining these relationships are hampered by one or more common methodological flaws. For instance, when the time to initiate treatment is investigated, a phenomenon called Immortal Time Bias should be considered.[14 15] This refers to 'a span of time in the observation or follow-up period of a cohort during which the outcome under study could not have occurred'.[14] As such, potential confounders including characteristic or prognostic differences in early versus late presenters can lead to a systematic underestimation or overestimation of an exposure's true influence on the outcome of interest.[14] Therefore, as a first step, we investigated the potential association between patient baseline characteristics and the timing of patient presentation to a specialty clinic for the assessment of SRC.[15] Using logistic regression, propensity scores were derived to predict early (≤7 days) versus late (8–28 days) presenters to control for systematic differences between participants who presented early and late to make both groups more directly comparable.[14 15] Based on these results, our next step and objective of this study were to investigate the relationship between early versus late time to presentation following SRC and recovery time using the previously developed propensity scores to control for confounding.

METHODS

Study design and setting

We conducted a historical cohort study using electronic healthcare records from the Complete Concussion Management Inc (CCMI) database with two phases of analysis. The CCMI database is an electronic health record system used by all CCMI-certified clinics to record patient information related to pre-season baseline testing, postinjury assessments and clinical notes.[15 16] Additional details on the CCMI database and data collected have been previously reported.[15 16] Patients provided consent for the use of their de-identified clinical records for research purposes during their registration with a CCMI-certified clinic.

Participants

Participants were male and female adolescent athletes between 12 and 18 years old who experienced an SRC and sought care from a CCMI-affiliated clinic in Canada from January 2017 (inception of the CCMI database) until December 2019 (to limit any potential effect of the coronavirus pandemic). We defined SRC according to the Berlin Consensus Statement on Concussion in Sport.[6] Participants who experienced a concussion not associated with sport (ie, motor vehicle accidents, workplace injuries, or blast injuries), moderate to severe traumatic brain injuries or those who presented later than 28 days post-SRC were excluded. We decided a priori to only include the index concussion if the same participants had multiple recorded SRCs as our previous study found delayed time to presentation for athletes who reported multiple SRCs.[15] Participants with pre-existing concussions were included in our study.

Exposure

Our exposure was the number of days between the athlete's self-reported date of SRC and their initial assessment. To remain consistent with our research and similar articles,[8 11 15] we defined 0–7 days as 'early' and 8–28 days as 'late'. This dichotomous exposure measure served as the outcome in the propensity model to derive propensity scores.

Propensity model independent variables

16 variables were selected a priori based on the scientific literature, clinical knowledge and data availability to build the propensity score model including demographic and preinjury information, injury characteristics and immediate post-concussion features.[15] Specific details were reported in our previous research.[15]

Data extraction procedure

De-identified data were extracted by an independent data management personnel to a password-protected spreadsheet and imported into a data analysis software (SPSS Statistics, V.26).

Primary outcome

Our primary outcome was time to recovery, that is, the number of days from the initial postinjury presentation to a CCMI clinic to clinical recovery (defined as the date of clinician clearance to return to sport). Surrogate metrics for concussion recovery were also collected to help understand a participant's health status related to their discharge status.[16]

Missing data analysis

Participants with incomplete data including date of discharge, recovery status and other follow-up information were included for analysis as censored observations at the date of their last clinic visit.[17] Study authors (SH-J, DYO and CM) held a meeting during data preparation for this study, prior to undertaking any analysis, to review participants with incomplete data and classify them as a loss to follow-up, ongoing injuries or discharged based on the clinical data recorded in the CCMI database (online supplemental appendix 1).

Analysis

Sample size requirements were determined using a statistical rule of thumb for logistic regression and survival analysis described by Harrell *et al*.[18] Propensity scores were first derived using the linear predictor from a multiple logistic regression model with early versus late CCMI clinical presentation as the outcome. Explanatory variables in the propensity score model included demographic and preinjury information, injury characteristics and immediate post-concussion symptoms. Survival analyses were conducted using Cox proportional hazards regression analysis to model the relationship between early versus late CCMI clinical presentation and time to recovery. The main exposure variable was clinical presentation time (early vs late) with covariates to control for confounding including the previously derived propensity score and sport type. The association between exposure and outcome was expressed using hazard rate ratios (HRR) with 95% CIs. In addition, the data were divided into five equal sized groups based on quintiles of the propensity scores and early versus late presenters were compared on the primary outcome time-to-recovery within each quintile using Kaplan-Meier curves.

Patient and public involvement

Patients or members of the public were not involved in the design or conduct of this current study.

Equity, diversity and inclusion statement

Members of our research team included senior, mid and early-career academics and clinicians, two of which are female. The study population included adolescents of different genders, demographics and sports in the CCMI database. As authors and population were limited to high-income countries, findings may not be generalisable to settings with fewer resources.

RESULTS

Participants

A total of 6125 patient records were retrieved from the database and 1429 records were excluded from analysis (figure 1). Primary reasons for exclusion included incomplete exposure data (ie, no recorded date of injury), mechanism of injury not related to sport and participants with multiple recorded SRCs within our dataset (only the index observation was included). A total

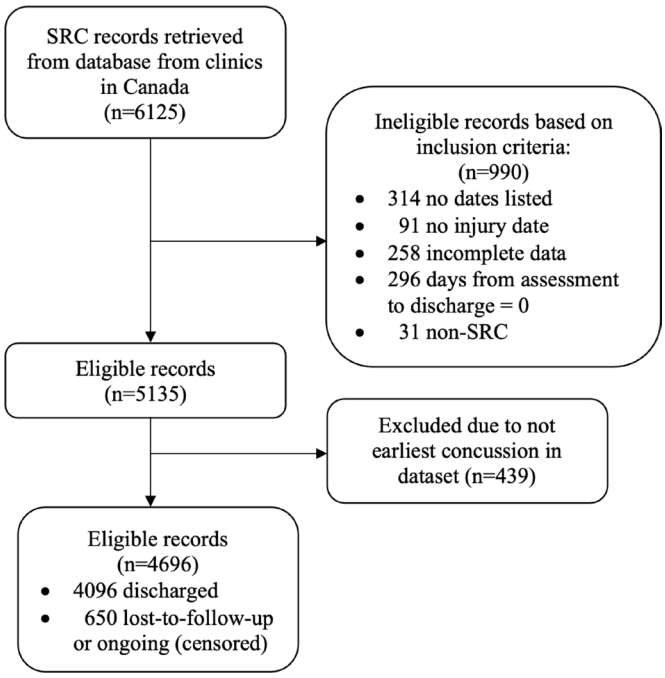

Figure 1 Cohort assembly. SRC, sport-related concussion.

of 4696 patient records were eligible for inclusion in the final analysis with 650 records recorded as censored (loss to follow-up or as an ongoing injury). The average age was 14.71 (±1.69 SD); 57.7% male. (table 1). The majority of athletes were evaluated in Ontario (44.0%). A total of 3404 participants (72.5%) presented early, whereas 1289 (27.5%) presented 8–28 days after their injury. Those in the early group presented on average 3.16 (±1.82 SD) days postinjury, versus 13.92 (±5.51 SD) days in the late group.

A completed pre-SRC baseline assessment was recorded for 1256 (26.7%) of the participants. Participants reported previously diagnosed anxiety 357 (7.60%), depression 153 (3.26%), headache 1220 (26.0%), learning disability 270 (5.75%) and attention deficit disorder or attention deficit hyperactivity disorder 272 (5.79%). The majority reported no previous SRCs 2920 (62.18%). Most participants reported no loss of consciousness 4098 (87.27%) and no post-traumatic amnesia 3934 (83.77%), but those who did experience similar rates of anterograde and retrograde amnesia. Participants had a mean post-concussion symptom scale score of 27.43 (±21.29)/132 and reported an average of 10.49 (±6.0)/22 possible symptoms. Most SRCs were sustained playing ice hockey 1995 (42.5%), followed by soccer 522 (11.1%), American football 485 (10.3%) and rugby (7s and 15s) 289 (6.2%).

Factors associated with early versus late presentation time

Like our previous study,[15] figure 2 presents side-by-side boxplots of propensity scores stratified by early versus late presenters and by quintile of propensity score. The plot shows a good overlap of distribution of propensity score between early and late presenters indicating the propensity score achieves a good balance of covariates between

Table 1 Participant characteristics

Characteristics	Count (% of column)		
	Early group (n=3404/4696; 72.5%)	Late group (n=1289/4696; 27.5%)	Early vs late groups (p value)*
Age (years) (mean±SD)	14.65±1.70	14.85±1.65	<0.001
Male (%)	2084 (61.2)	673 (52.2)	<0.001
Province			
Atlantic provinces	390 (11.5)	123 (9.54)	<0.001
Quebec	267 (7.84)	127 (9.85)	
Ontario	1476 (43.4)	587 (45.5)	
Manitoba	5 (0.15)	5 (0.39)	
Saskatchewan	479 (14.1)	149 (11.6)	
Alberta	238 (6.99)	67 (5.20)	
British Columbia	549 (16.1)	231 (17.9)	
Time to clinical presentation (days) (mean±SD)	3.16±1.82	13.92±5.51	<0.001
Completed baseline (%)	1111 (32.6)	145 (11.2)	<0.001
History of diagnosed anxiety (%)	248 (7.29)	109 (8.46)	0.186
History of diagnosed depression (%)	100 (2.94)	53 (4.11)	0.049
History of diagnosed headache (%)	844 (24.8)	376 (29.2)	0.002
History of diagnosed learning disability (%)	206 (6.05)	64 (4.97)	0.155
History of diagnosed ADD/ADHD (%)	192 (5.64)	80 (6.20)	0.455
Number of previously self-reported SRCs			
Mean±SD	0.57±0.95	0.74±1.21	<0.001
0	2163 (63.5)	757 (58.7)	
1	813 (23.9)	315 (24.4)	
2	264 (7.76)	111 (8.61)	
≥3	164 (4.82)	106 (8.22)	
Loss of consciousness (%)			
Yes	209 (6.14)	90 (6.98)	0.549
No	2978 (87.5)	1120 (86.9)	
Unsure	217 (6.37)	79 (6.13)	
Post-traumatic amnesia (%)			
Anterograde	291 (8.55)	106 (8.22)	0.073
Retrograde	244 (7.17)	118 (9.15)	
None	2869 (84.3)	1065 (82.6)	
PCS score (/132) (mean±SD)	27.55±21.21	27.11±21.5	0.533
PCSS symptom number (/22) (mean±SD)	10.53±5.910	10.4±6.221	0.519
Mechanism of injury (%):			
Hockey	1502 (44.1)	493 (38.2)	<0.001
Soccer	372 (10.9)	150 (11.6)	
Football	364 (10.7)	121 (9.39)	
Rugby	195 (5.72)	94 (7.29)	
Basketball	208 (6.11)	77 (5.97)	
Lacrosse	91 (2.67)	26 (2.02)	
Skiing	100 (2.94)	55 (4.27)	
Volleyball	122 (3.58)	39 (3.03)	
Cheerleading	92 (2.70)	34 (2.64)	

Continued

Table 1 Continued

Characteristics	Count (% of column)		
	Early group (n=3404/4696; 72.5%)	Late group (n=1289/4696; 27.5%)	Early vs late groups (p value)*
Ringette	73 (2.14)	36 (2.79)	
Martial arts	64 (1.88)	34 (2.64)	
Watersport	41 (1.20)	15 (1.16)	
Skating	32 (0.94)	14 (1.09)	
Gymnastics	23 (0.68)	14 (1.09)	
Baseball	24 (0.70)	22 (1.71)	
Cycling	24 (0.70)	13 (1.01)	
Dance	13 (0.38)	11 (0.85)	
Dodgeball	8 (0.23)	6 (0.47)	
Equestrian	12 (0.35)	11 (0.85)	
Other	45 (1.32)	24 (1.86)	
Location of impact—head (%)			
Crown	71 (2.08)	23 (1.78)	0.513
Frontal bone—left	705 (20.7)	275 (21.3)	0.629
Frontal bone—right	884 (26.0)	310 (24.1)	0.176
Temporal bone—left	436 (12.8)	156 (12.1)	0.552
Temporal bone— right	440 (12.9)	150 (11.6)	0.238
Parietal bone—left	151 (4.43)	75 (5.82)	0.048
Parietal bone—right	187 (5.49)	91 (7.06)	0.042
Occipital bone—left	708 (20.8)	235 (18.2)	0.052
Occipital bone—right	757 (22.2)	256 (19.9)	0.080
Location of impact—body (%)			
Front	328 (9.66)	121 (9.39)	0.780
Rear	320 (9.39)	93 (7.21)	0.019
Left side	227 (6.66)	77 (5.97)	0.392
Right side	250 (7.34)	79 (6.13)	0.147

*Two-sided t-test or χ^2.
ADD/ADHD, attention deficit disorder/attention deficit hyperactivity disorder; PCS, post-concussion syndrome; PCSS, post-concussion symptom scale; SRC(s), sport-related concussion(s).

the two groups. Additional details are included in online supplemental appendices 2 and 3.

Cox proportional hazards regression

Early presentation for care following SRC was associated with faster time to recovery (HRR 1.23; 95% CI 1.14 to 1.32, p<0.001) after adjusting for covariates including propensity score quintile strata and the categorical sport variable. Kaplan-Meier graphs modelling the relationship between time to presentation after SRC and clinical recovery showed a median of 18 versus 22 days between the early and late groups, respectively (figure 3). This relationship was also seen with Kaplan-Meier graphs between early and late groups within propensity quintiles 1–3. Quintiles 4 and 5, however, showed no difference in median recovery times between early and late groups (online supplemental appendices 4 and 5).

DISCUSSION

This study examined the relationship between time to clinical presentation following SRC and the time to clinical clearance to return to sport in adolescent Canadian athletes. Overall, our results showed that early presentation was associated with a faster recovery (18 days) compared with later presentation (22 days) after adjustment for all covariates including propensity score strata. Further analysis within the quintiles of the propensity score showed similar findings; however, quintiles 4 and 5 did not show any differences in median recovery time between the early and late groups. While these findings support earlier presentations for care can expedite recovery in adolescents with SRC, our results are more modest compared with the related literature.[8 11–13 19] We believe that there are several explanatory factors for our findings.

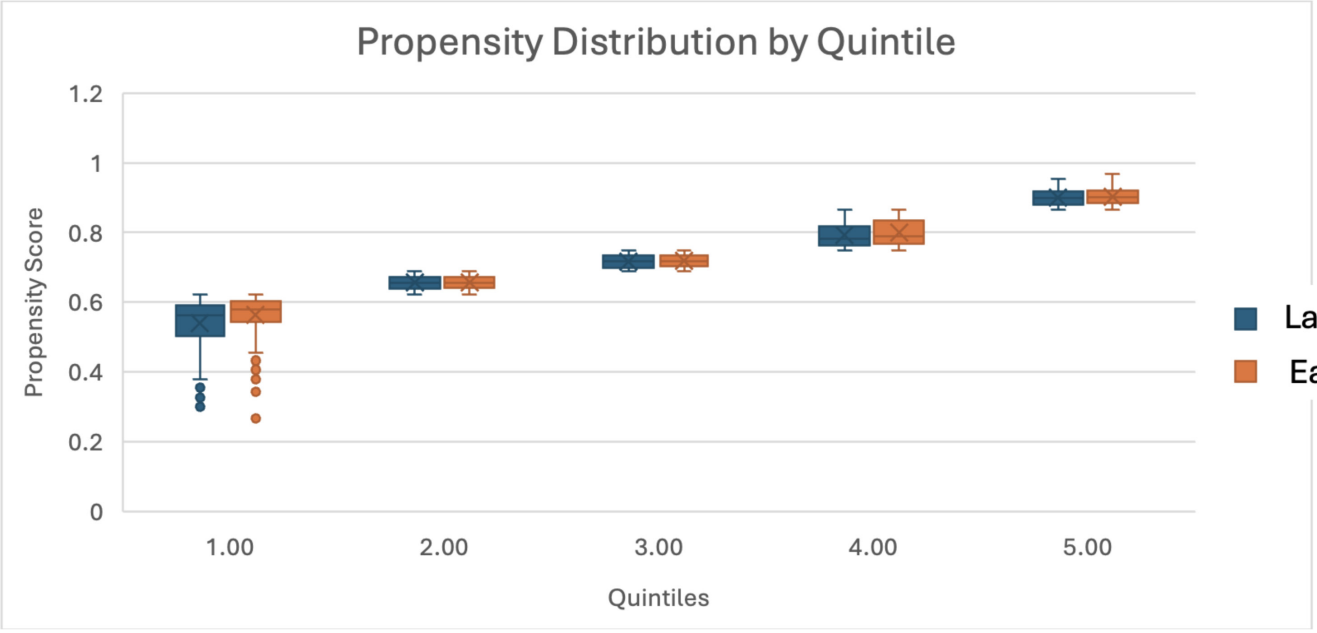

Figure 2 Propensity score distribution by quintile (Q1–Q5) dichotomised by early (E) or late (L) grouping. Boxes represent the IQRs (25th percentile to 75th percentile) of each quintile for both the early (orange) and late (blue) groups. Median values are represented by the line in the middle of the box, and whiskers represent the minimum and maximum propensity score values. Circles plotted beyond the whiskers denote outlier data.

Some studies only include 'complete' records and exclude subjects who have not yet recovered at the time of data extraction/analysis. When the time to an event serves as an outcome and survival methods are employed for data analysis, these incomplete observations can be considered as censored observations. Excluding them would, in fact, result in an overestimation of the probability of recovery at any specific time point.[17] If there is varying exclusion of incomplete observations between individuals presenting early and late, the association between time to presentation and time to recovery will be biased with the direction of the bias dependent on the direction of differential exclusion.

Second, some studies will incorporate the exposure (time from concussion to clinical presentation) within the outcome (time from concussion to recovery) which

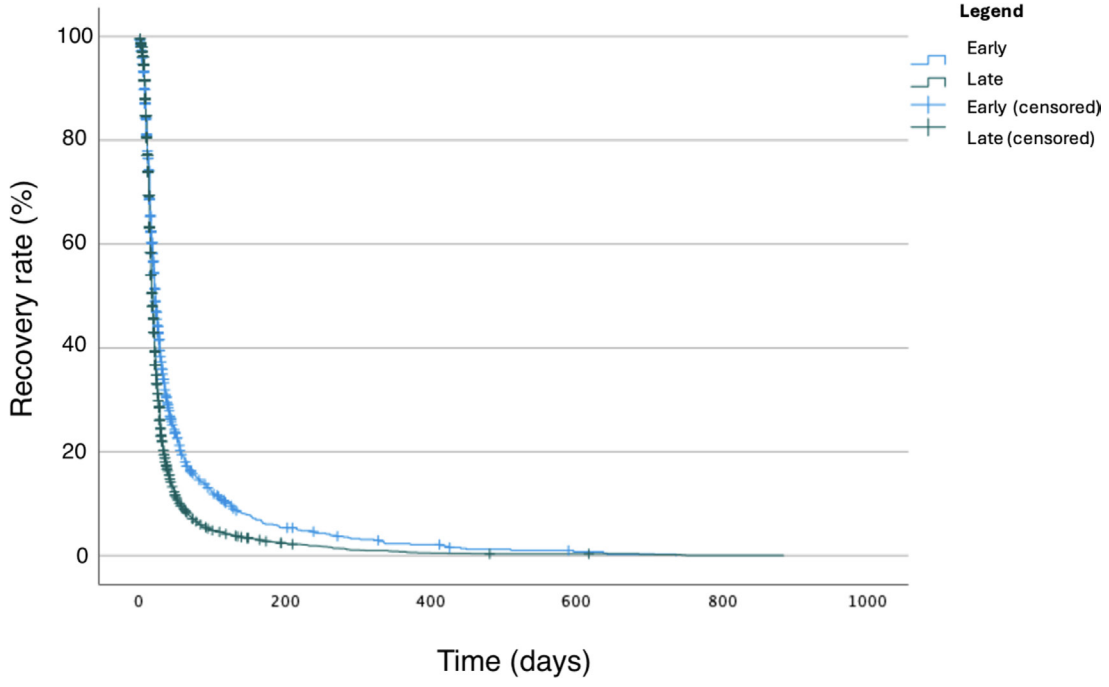

Figure 3 Kaplan-Meier curves for time to patient discharge based on the time of initial assessment dichotomised by early (green) and late (blue) after adjustment for all covariates including propensity score strata.

is commonly described in pharmacological literature as the immortal time bias.[12 13 16 19–21] In short, when time to clinical presentation is embedded in time to recovery, subjects who present for care longer following SRC will experience a longer time from concussion to recovery. Furthermore, subjects cannot have a time to recovery shorter than time to clinical presentation.

Thirdly, subjects who present later for care rather than earlier are likely at a different place in the natural history of concussion recovery than those presenting earlier and are prognostically different when they present after SRC.[15] While some studies adjusted for these differences using regression control methods, it is unclear whether the factors used were sufficient to fully control for prognostic differences.[12 13 16 19] To achieve a better balance between groups, we used a propensity model.[15] Our propensity score demonstrated modest ability (area under curve (AUC)=0.68; 95% CI 0.66 to 0.70, p=0.318) to classify early versus late presenters. Furthermore, the boxplot graphs in our study showed significant overlap demonstrating good balance between subjects in each quintile.

Clinical implications

The results of this study underscore the importance of early clinical assessment and intervention for adolescent athletes who suffer from SRC. Given the high incidence of SRC among adolescents and the documented increase in concussion diagnoses over the past decades,[3 4] early intervention allows for timely management, which may reduce the severity and duration of symptoms, thereby facilitating a quicker return to school and sports activities. This can also mitigate the negative emotional and cognitive impacts associated with prolonged symptoms.[1 5] Early intervention may also help identify individuals who are 'poor copers' with a potentially protracted recovery trajectory that may benefit from earlier referral to specific concussion specialists.[6] Additionally, educational initiatives targeting athletes, parents, coaches and educators about the signs of concussion and the importance of early medical consultation could enhance early care-seeking behaviours, which could lead to improved recovery outcomes.[6 7]

Strengths and limitations

To our knowledge, this study is among the first to adjust for confounding in our analysis with a propensity model to control for systemic differences and make participants more comparable in an observational study design.[17 22] Additionally, our study uses a large national database and large sample size far exceeding the estimated minimum requirement of 320 subjects while planning the study.[15] Our propensity model was robust consisting of 16 covariates that have been reported to be statistically and clinically associated with prognostic outcomes in adolescents with concussion.[15] Additional methodological strengths include investigating patients from time from injury to clinical presentation (exposure) to time to clinical recovery from initial presentation (outcome) to avoid the immortal time bias and an overestimation of the strength of association between timing of presentation and time to clinical recovery.[21] Our study also included subjects with incomplete data as censored observations control for overestimation and/or underestimation of our results as compared with other related observational studies.[12 13 16 19 20] At last, our study included concussion patients presenting to outpatient sport-medicine and/or injury rehabilitation clinics.[16]

Because of the observational nature of the study, we cannot dismiss the potential existence of residual and unmeasured confounding factors. Previous studies have reported high initial pain and disability levels, high symptom burden, poor recovery expectations and pre-existing headache or mental health issues as potential negative prognostic factors.[23] It is possible that other factors exist that could potentially influence athlete presentation in both the early and late groups. Similarly, all observational studies[12 13 16 19 20] are missing an important subgroup of subjects—individuals who sustained an SRC that did not present to the clinic early and recovered without seeking care. Patients presenting later to the clinic in these studies do so because they have not yet fully recovered. Excluding this subgroup from the studies will result in an overestimation of the time to recovery for those patients who presented late to the clinic, thus biasing the association between time to clinical presentation and time to recovery. At last, our study also used clinical data that was reliant on community providers completing and dating records appropriately.[16] While the licenced healthcare providers were trained in the concussion management protocols and clinical record keeping, there may have been variability in how rigorous they were with record keeping.[16]

CONCLUSIONS

Using a propensity score methodology, in our cohort of over 4900 Canadian adolescent athletes, both early and late groups showed similar trajectories for recovery; however, earlier presenters tended to recover faster. A small minority in both the early and late groups showed protracted recovery times, suggesting that prognostic differences were not accounted for by our propensity model. These findings provide additional observational evidence that earlier presentation for care following SRC may lead to faster recovery times.

Author affiliations
[1]Graduate Studies, Canadian Memorial Chiropractic College, Toronto, Ontario, Canada
[2]Faculty of Health Sciences, Ontario Tech University Centre for Disability Prevention and Rehabilitation, Ontario Tech University and Canadian Memorial Chiropractic College, Ontario Tech University, Oshawa, Ontario, Canada
[3]Complete Concussion Management Inc, Toronto, Ontario, Canada
[4]Department of Research and Innovation, Canadian Memorial Chiropractic College, Toronto, Ontario, Canada
[5]University of Toronto Dalla Lana School of Public Health, Toronto, Ontario, Canada

Contributors All authors contributed to designing the study. DYO, CM and SH-J contributed to the acquisition, analysis or interpretation of data. DYO and SH-J

contributed to interpreting the data and revising the draft and final manuscript. All authors agreed to the final version of the manuscript. DYO and SH-J act as a guarantor and take responsibility for the work, have access to the data and control the decision to publish. DYO is the guarantor.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Disclaimer The content of this report is solely the responsibility of the authors and does not necessarily represent the official view of CMCC, Ontario Tech University Institute for Disability and Rehabilitation Research at Ontario Tech University and Canadian Memorial Chiropractic College, nor the University of Toronto.

Competing interests CM is the founder and current president of Complete Concussion Management Inc. (CCMI) but did not receive any personal fees in relation to the conduct of this study. DYO has completed the CCMI Healthcare Practitioner Certification Course but did not receive any personal fees in relation to the conduct of this study. No other disclosures were reported.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Ethics approval for this study was obtained from the Canadian Memorial Chiropractic College research ethics board (Certificate # 2106X01).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

ORCID iD

David Youngwoo Oh http://orcid.org/0009-0005-7396-0082

REFERENCES

1 Kimbler DE, Murphy M, Dhandapani KM. Concussion and the adolescent athlete. *J Neurosci Nurs* 2011;43:286–90.
2 Pfister T, Pfister K, Hagel B, *et al*. The incidence of concussion in youth sports: a systematic review and meta-analysis. *Br J Sports Med* 2016;50:292–7.
3 Veliz P, McCabe SE, Eckner JT, *et al*. Prevalence of Concussion Among US Adolescents and Correlated Factors. *JAMA* 2017;318:1180–2.
4 Reid DBC, Shah KN, Baum EJ, *et al*. Concussion: Mechanisms of Injury and Trends from 1997 to 2019. *R I Med J (2013)* 2020;103:71–5.
5 Halstead ME, Walter KD, Moffatt K, *et al*. Sport-Related Concussion in Children and Adolescents. *Pediatrics* 2018;142:e20183074.
6 McCrory P, Meeuwisse W, Dvorak J, *et al*. Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. *Br J Sports Med* 2016;51:838–47.
7 Lithopoulos A, Dawson J, Reed N, *et al*. Living Guidelines for the Diagnosis and Management of Adult and Pediatric Concussion. *J Neurotrauma* 2022;39:243–4.
8 Lawrence DW, Richards D, Comper P, *et al*. Earlier time to aerobic exercise is associated with faster recovery following acute sport concussion. *PLoS ONE* 2018;13:e0196062.
9 Leddy JJ, Haider MN, Ellis MJ, *et al*. Early Subthreshold Aerobic Exercise for Sport-Related Concussion. *JAMA Pediatr* 2019;173:319.
10 Ledoux A-A, Barrowman N, Bijelić V, *et al*. Is early activity resumption after paediatric concussion safe and does it reduce symptom burden at 2 weeks post injury? The Pediatric Concussion Assessment of Rest and Exertion (PedCARE) multicentre randomised clinical trial. *Br J Sports Med* 2022;56:271–8.
11 Barnhart M, Bay RC, Valovich McLeod TC. The Influence of Timing of Reporting and Clinic Presentation on Concussion Recovery Outcomes: A Systematic Review and Meta-Analysis. *Sports Med* 2021;51:1491–508.
12 Kara S, Crosswell H, Forch K, *et al*. Less Than Half of Patients Recover Within 2 Weeks of Injury After a Sports-Related Mild Traumatic Brain Injury: A 2-Year Prospective Study. *Clin J Sport Med* 2020;30:96–101.
13 Kontos AP, Jorgensen-Wagers K, Trbovich AM, *et al*. Association of Time Since Injury to the First Clinic Visit With Recovery Following Concussion. *JAMA Neurol* 2020;77:435.
14 Suissa S. Immortal time bias in pharmaco-epidemiology. *Am J Epidemiol* 2008;167:492–9.
15 Germann D, Cancelliere C, Kazemi M, *et al*. Characteristics of adolescent athletes seeking early versus late care for sport-related concussion. *J Can Chiropr Assoc* 2021;65:260–74.
16 Pratile T, Marshall C, DeMatteo C. Examining how time from sport-related concussion to initial assessment predicts return-to-play clearance. *Phys Sportsmed* 2022;50:132–40.
17 Watt DC, Aitchison TC, MacKie RM, *et al*. Survival analysis: the importance of censored observations. *Melanoma Res* 1996;6:379–85.
18 Harrell FE. *Regression Modeling Strategies, with Applications to Linear Models, Survival Analysis and Logistic Regression*. Springer, 2001.
19 Eagle SR, Puligilla A, Fazio-Sumrok V, *et al*. Association of time to initial clinic visit with prolonged recovery in pediatric patients with concussion. *J Neurosurg Pediatr* 2020;26:165–70.
20 Bock S, Grim R, Barron TF, *et al*. Factors associated with delayed recovery in athletes with concussion treated at a pediatric neurology concussion clinic. *Childs Nerv Syst* 2015;31:2111–6.
21 Lévesque LE, Hanley JA, Kezouh A, *et al*. Problem of immortal time bias in cohort studies: example using statins for preventing progression of diabetes. *BMJ* 2010;340:b5087.
22 OED. Sport, n.1, Web 9. Oxford University Press; 2019.
23 Reed N, Zemek R, Dawson J, *et al*. Living Guideline for Diagnosing and Managing Pediatric Concussion. *Br J Sports Med* 2021;55:279–89.