ISSN 0008-3194 (p)/ISSN 1715-6181 (e)/2021/260–274/$2.00/©JCCA 2021

Characteristics of adolescent athletes seeking early versus late care for sport-related concussion

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Objectives: *1) To determine which characteristics of adolescent athletes with SRC are associated with 'early' versus 'late' presentation for multimodal treatment; 2)*

Commotion cérébrale liée au sport (CCLS) : caractéristiques des athlètes adolescents consultant rapidement et celles des adolescents qui consultent tardivement

Objectifs : *1) Trouver les caractéristiques des athlètes adolescents ayant subi une CCLS qui sont associées à la*

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Author contributions: Drs. Germann and Hogg-Johnson had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: All authors. *Acquisition, analysis, or interpretation of data*: All authors.
Drafting of the manuscript: Germann, Hogg-Johnson. *Critical revision of the manuscript for important intellectual content*: All authors. *Statistical analysis*: Germann, Hogg-Johnson.

Conflict of Interest Disclosures: Dr. Marshall 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. Dr. Germann 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. No funding was provided for the completion of this study. Carol Cancelliere holds a Research Chair in Knowledge Translation in the Faculty of Health Sciences, Ontario Tech University, which is funded by the Canadian Chiropractic Research Foundation. 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.

to build a propensity score to investigate the effects of treatment timing during the management of SRCs.

Methods: *Associations between early (0-7 days) versus late (8-28 days) presentation for treatment and pre-specified sociodemographic, pre-injury and injury characteristics were investigated in a historical cohort study of 2949 multi-sport athletes across Canada aged 12-18 years diagnosed with a SRC in community-based healthcare clinics.*

Results: *Early presentation was associated with being male, completing a pre-injury baseline assessment, and responding 'yes' or 'no' to having a diagnosed learning disability. Older athletes who reported previous SRCs were less likely to present early. The propensity score demonstrated an area under the curve of 0.71 (95% CI, 0.69 to 0.73).*

Conclusions: *Male athletes with a completed baseline assessment were more likely to seek early treatment following a SRC, and older athletes who reported a greater number of previous SRCs were less likely to present early. External validation of the propensity score is needed before examining the impact of treatment timing on adolescent athlete recovery outcomes.*

(JCCA. 2021;65(3):260-274)

KEY WORDS: chiropractic, concussion, mild traumatic brain injury, multi-modal treatment, rehabilitation, sport related concussion

consultation précoce et à une consultation tardive; 2) établir *un score de propension pour* étudier *les effets du moment du traitement pendant la prise en charge de la CCLS.*

Méthodologie : *Les liens entre la consultation précoce (de 0 à 7 jours) et la consultation tardive (de 8 à 28 jours) et les caractéristiques sociodémographiques, les caractéristiques avant la blessure et les caractéristiques après des blessure prédéterminées ont* été *examinés au cours d'une* étude de *cohorte historique menée auprès de 2 949 adolescents multisports répartis dans toutes les régions du Canada,* âgés *de 12 à 18 ans, chez lesquels une CCLS avait* été *diagnostiquée dans des cliniques de santé communautaires.*

Résultats : *La consultation précoce a* été *associée au sexe masculin, à une* évaluation *de départ avant la blessure et à la présence ou à l'absence d'un trouble de l'apprentissage. Les athlètes plus* âgés *ayant signalé des CCLS antérieures* étaient *moins susceptibles de consulter précocement. Le score de propension a démontré une aire sous la courbe de 0,71 (IC à 95 % : 0,69 à 0,73).*

Conclusions : *Les athlètes masculins ayant subi une* évaluation *de départ* étaient *plus susceptibles de consulter précocement après une CCRS alors que les athlètes* âgés *ayant déclaré un plus grand nombre de CCRS antérieures* étaient *moins susceptibles de consulter précocement. Une validation externe du score de propension serait nécessaire avant d'examiner l'effet du moment de la consultation sur les résultats de récupération chez les athlètes adolescents.*

(JCCA. 2021;65(3):260-274)

MOTS CLÉS : chiropratique, commotion, lésion cérébrale traumatique légère, traitement multimodal, réadaptation, commotion liée au sport

Introduction

Sport-related head and neck injuries, including concussions, are common in young athletes.[1,2] In a recent survey of 13,000 adolescents (Grade 8, 10, and 12) in the US, 19.5% reported having at least one concussion in their lifetime.[3] However, this figure is thought to be grossly underestimated.[4] Sports with the highest rates of concussion for athletes less than 18 years old are Rugby (4.18/1000 athlete exposures (AEs)), Ice hockey (1.20/1000 AEs), American football (0.53/1000 AEs).[5]

The symptoms associated with sport-related concussion (SRC) may be of cognitive, visual, vestibular, physiological, or cervical spine origin.[6–9] Such symptoms can have a significant negative impact on an athlete's educational and sport-related activities and aspirations. Recent evidence suggests that greater symptom severity is associated with higher levels of concern for reduced academic performance, and more school-related problems in adolescents.[10] It has also been shown that high school students not yet recovered from concussion report significantly more perceived adverse academic effects than younger students suffering from SRC.[10] The typical recovery time for adolescents with concussion is already greater than that seen in adults[5], at four weeks [8,11] compared to the usual 10 to 14 days seen in adults[11]. This further reinforces the need for greater SRC research in this population.

Emerging evidence from observational studies suggests that favourable recovery outcomes are obtained through the use of individualized, multi-modal plans of management [6,8,9] particularly if initiated early after concussion versus later[12,13]. However, when the timing of treatment initiation is of primary interest, a phenomenon called Immortal Time Bias – "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], can lead to a systematic under-or-overestimation of an intervention's true influence on the outcome of interest. Therefore, the apparent treatment effects seen in these previous observational studies may, in part, be due to characteristic or prognostic differences between the athletes who present for treatment earlier versus later.

Propensity scores provide a methodology for observational studies that may be useful in controlling for systematic differences among participants by making those participants within the exposed/experimental and non-exposed/control groups more directly comparable.[15] Further, such methodology may allow for a greater number of covariates to be adjusted for in the model.

There are currently no studies that describe the association between patient characteristics and the timing of patient presentation for treatment, nor completely describe a propensity score that can be used to balance subjects on such characteristics in future observational studies. We hypothesized that those with a greater number of previous concussions would present for care earlier, and that individuals with a previous diagnosis of an anxiety disorder, depression, or with a history of headache would present for treatment later. Similarly, we expected that athletes who suffered loss of consciousness (LOC), post-traumatic amnesia (PTA), or post-traumatic seizures (PTS) at the time of their concussion would also present at a later time[12], as they may initially be sent to the hospital rather than a treatment clinic.

This study represents the initial step in a line of research aimed at better understanding the relationship between timing of treatment and athlete recovery outcomes. Therefore, our objectives were to 1) determine which pre-determined characteristics of adolescent athletes (12-18 years old) with SRC are associated with 'early' versus 'late' presentation to concussion management clinics for multimodal treatment; 2) to build a propensity score to investigate the effects of treatment timing during the management of SRCs in future studies. This study is reported in compliance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement.[16]

Methods

Study design and setting

We conducted a historical cohort study using a concussion management database containing electronic healthcare records from community-based healthcare clinics in Canada. The Complete Concussion Management Inc. (CCMI) database is an electronic medical record system used by healthcare providers who undergo additional evidence-based training in concussion management provided by CCMI to document patient characteristics and baseline testing (e.g., demographics, geographic location, sport participation, and pre-injury conditions), post-injury concussion assessments (e.g., validated patient-reported outcome measures such as the Post-Concussion Symptom Scale (PCSS) score, and physical examination findings), and clinical notes. Ethical approval was obtained from the Canadian Memorial Chiropractic College (CMCC) research ethics board (Certificate #1907X02).

Participants

We investigated the records of athletes who sought care for a SRC at a community healthcare clinic between January 2017 and August 2019. Eligible participants were male and female athletes between 12-18 years of age. We excluded participants with concussions/mild traumatic brain injuries that were not associated with sport (i.e. motor vehicle accidents, workplace injuries, blast injuries), those with moderate or severe traumatic brain injuries, and those presenting later than 28 days post-concussion.

Sport-Related Concussion (SRC) case definition

SRC was defined according to the Berlin Consensus

Statement on Concussion in Sport.[11] SRC is the onset of short-lived impairments of neurological function following a direct blow to the head, face, neck, or elsewhere on the body with an impulsive force transmitted to the head.[11]

Data extraction procedure
De-identified data was extracted by independent data management personnel to a password protected spreadsheet and imported into a data analysis software (SPSS Statistics, version 26).

Primary outcome
Our outcome of interest was the time to presentation for care defined as the number of days between the self-reported date of the athlete's concussion and the date of their initial assessment at a healthcare clinic. A presentation period of 0-7 days post-injury was selected to define the 'early' group to remain consistent with the most recent published literature[12], while a period of 8-28 days defined the 'late' group[12] considering that most concussive symptoms in adolescents resolve within one month[11].

Independent variables
We selected sixteen variables *a priori* based on the scientific literature and clinical knowledge including demographic and pre-injury information (i.e. age, sex, geographic location, number of previous SRCs, completion of a baseline assessment, or a history of anxiety, depression, headache, learning disability, or ADD/ADHD), injury characteristics (i.e. sport played at the time of injury, location of impact on the head or body), and immediate post-concussion features (i.e. loss of consciousness, post-traumatic amnesia, post-traumatic seizures).

Sample size
In order to estimate a minimum sample size, we applied a general statistical rule of thumb for logistic regression described by Harrell, requiring at least 10 events and non-events per independent variable (i.e., 160 events and 160 non-events).[17]

Analysis
We analyzed the data descriptively using frequencies or means (standard deviations (SD)) and used two-tailed t-tests and Pearson χ^2 tests to analyze the relationships between the independent variables and outcome group.

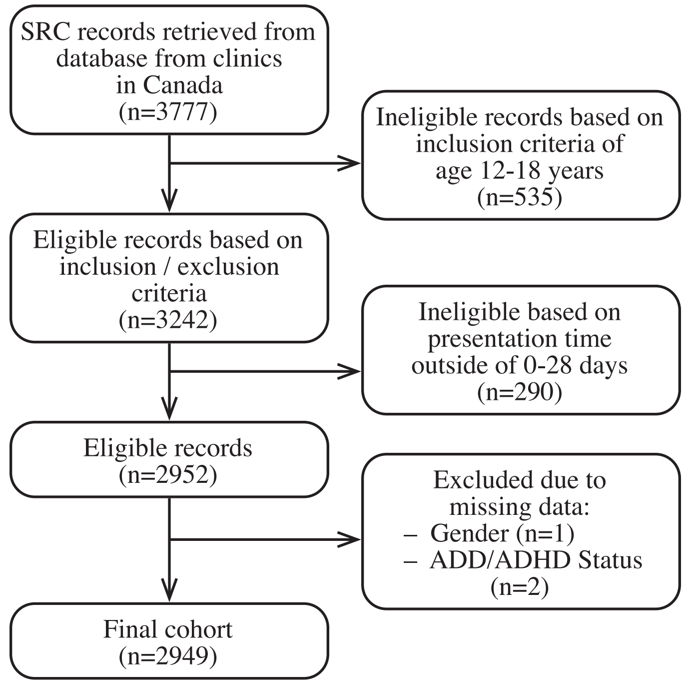

Figure 1.
Cohort Assembly. ADD/ADHD = Attention deficit disorder / attention deficit hyperactivity disorder; SRC = Sport-related concussion;

A multiple logistic regression model was fit with all the pre-determined independent variables. Associations were expressed as odds ratios with 95% confidence intervals.

The predicted probabilities of an athlete presenting early vs. late obtained from the multiple logistic regression was used to develop a propensity score.[15] Quintile stratification by propensity score was then used to examine whether there was a balance of early and late presenters within quintiles.[11] Overall performance of the propensity score model was gauged by calculating the Area Under the Curve (AUC) and model-fit assessed via the Hosmer & Lemeshow Goodness-of-Fit test.[18]

Results

Cohort Assembly & Missing Data
A total of 3777 records were retrieved from the database, and 2949 patient records were included in the final analysis (Figure 1). Less than 10% of the retrieved records had missing data (225/2949, 7.5%). Three records (0.1%) with

Table 1.
Participant characteristics

Characteristic	Count (% of Column)		
	Early Group (N = 2163/2949; 73.3%)	**Late Group (N = 786/2949; 26.7%)**	**Early vs. Late Groups (P-Value)a**
Age (years), (mean ±SD)			
Mean ± SD	14.30 ± 1.45	14.56 ± 1.43	<.001
Sex			
Male	1257 (58.1)	402 (51.1)	.001
Province			
Atlantic Provinces	224 (10.4)	71 (9.0)	<.001
Quebec	311 (14.4)	150 (19.1)	
Ontario	784 (36.2)	287 (36.5)	
Saskatchewan	305 (14.2)	89 (11.3)	
Alberta	166 (7.7)	55 (7.0)	
British Columbia	373 (17.2)	134 (17.0)	
Time to Clinic Presentation (days)			
Mean ± SD	3.12 ± 1.84	14.07 ± 5.48	<.001
Completed Baseline			
Yes	911 (42.1)	163 (20.7)	<.001
History of Diagnosed Anxiety			
Yes	164 (7.6)	69 (8.8)	.287
History of Diagnosed Depression			
Yes	52 (1.3)	28 (6.6)	.087
History of Diagnosed Headache			
Yes	21 (1.0)	11 (1.4)	.321
History of Diagnosed Learning Disability			
Yes	106 (4.9)	43 (5.5)	<.001
No	1992 (92.1)	631 (80.3)	
Missing	65 (3.0)	112 (14.2)	
History of Diagnosed ADD/ADHD:			
ADD	29 (1.3)	18 (2.3)	.089
ADHD	76 (3.5)	35 (4.5)	
None	2058 (95.1)	733 (93.3)	
Number of Previous self-reported SRCs:			
Mean ± SD	0.54 ± 0.83	0.67 ± 0.94	.001
0	1358 (62.8)	458 (58.3)	
1	530 (24.5)	196 (24.9)	
2	179 (8.3)	68 (8.7)	
≥3	96 (4.4)	64 (8.1)	
Loss of Consciousness:			
Yes	115 (5.3)	55 (7.0)	.173
No	1912 (88.4)	688 (87.5)	
Unsure	136 (6.3)	43 (5.5)	
Post-Traumatic Amnesia:			
Anterograde	162 (7.5)	69 (8.8)	.152
Retrograde	150 (6.9)	67 (8.5)	
None	1851 (85.6)	650 (82.7)	
Post-Traumatic Seizures:			
Yes	24 (1.1)	9 (1.1)	.595
No	2103 (97.2)	768 (97.7)	
Missing	36 (1.7)	9 (1.1)	

[a] Two-sided t-test or chi-square
ADD/ADHD = Attention Deficit Disorder / Attention Deficit Hyperactivity Disorder; LOC = Loss of Consciousness; PCS = Post-Concussion Syndrome; PCSS = Post-Concussion Symptom Score; SD = Standard Deviation; SRC(s) = Sport Related Concussion(s); WAD = Whiplash Associated Disorder.

Table 1.
Participant characteristics – Continued

Characteristic	Count (% of Column)		
	Early Group (N = 2163/2949; 73.3%)	Late Group (N = 786/2949; 26.7%)	Early vs. Late Groups (P-Value)a
PCSS Score (/132)			
Mean ± SD	26.6 ± 21.8	25.35 ± 21.25	.167
PCSS Symptom Number (/22)			
Mean ± SD	10.12 ± 6.098	9.80 ± 6.37	.212
Mechanism of Injury:			
Hockey	916 (42.3)	282 (35.9)	<.001
Soccer	275 (12.7)	102 (13.0)	
Football	213 (9.8)	58 (7.4)	
Rugby	128 (5.9)	64 (8.1)	
Basketball	126 (5.8)	47 (6.1)	
Lacrosse	86 (4.0)	19 (2.4)	
Skiing	60 (2.8)	40 (5.1)	
Volleyball	60 (2.8)	23 (2.9)	
Cheerleading	55 (2.5)	24 (3.1)	
Ringette	50 (2.3)	17 2.2)	
Martial Arts	39 (1.8)	24 (3.1)	
Watersport	31 (1.4)	9 (1.1)	
Skating	17 (0.79)	9 (1.1)	
Gymnastics	18 (0.83)	9 (1.1)	
Baseball	15 (0.69)	10 (1.3)	
Cycling	8 (0.37)	8 (1.0)	
Dance	9 (0.42)	6 (0.76)	
Dodgeball	6 (0.28)	6 (0.76)	
Equestrian	7 (0.32)	2 (0.25)	
Other	44 (2.0)	27 (3.4)	
Location of Impact – Head			
Crown	28 (1.3)	12 (1.5)	.630
Frontal Bone – Left	436 (20.2)	164 (20.9)	.673
Frontal Bone – Right	545 (25.2)	199 (25.3)	.946
Temporal Bone – Left	258 (11.9)	90 (11.5)	.722
Temporal Bone – Right	265 (12.3)	92 (11.7)	.687
Parietal Bone – Left	97 (4.5)	45 (5.7)	.164
Parietal Bone – Right	130 (6.0)	51 (6.5)	.632
Occipital Bone – Left	468 (21.6)	145 (18.4)	.059
Occipital Bone – Right	492 (22.7)	162 (20.6)	.217
Location of Impact – Body			
Front	191 (8.8)	79 (10.1)	.310
Rear	218 (10.1)	62 (7.9)	.073
Left Side	130 (6.0)	36 (4.6)	.136
Right Side	143 (6.6)	52 (6.6)	.996
Diagnosis at Time of Assessment (community clinic):			
WAD	861 (39.8)	184 (23.4)	<.001
Chronic WAD	0 (0.00)	34 (4.3)	<.001
PCS	1 (0.05)	75 (9.5)	<.001
SRC with LOC	131 (6.0)	62 (7.9)	.075
SRC without LOC	1645 (76.1)	521 (66.3)	<.001
None	230 (10.6)	119 (15.1)	.001
Other	54 (2.5)	24 (3.1)	.405
Not Provided	21 (0.97)	5 (0.64)	.390

[a] Two-sided t-test or chi-square
ADD/ADHD = Attention Deficit Disorder / Attention Deficit Hyperactivity Disorder; LOC = Loss of Consciousness; PCS = Post-Concussion Syndrome; PCSS = Post-Concussion Symptom Score; SD = Standard Deviation; SRC(s) = Sport Related Concussion(s); WAD = Whiplash Associated Disorder.

small amounts of missing data (gender = 1 record, ADD/ADHD status = 2 records) that interfered with cross-tabulation analyses were removed. For two predictors with larger amounts of missing data (post-traumatic seizures = 45 (1.5%) records, and history of learning disability = 177 (6%) records) that did not interfere with statistical testing, missing was maintained as a category and they were included in the model with three categories – Yes, No and Missing.

Participants

Participants were aged 14.37 (± 1.45) years (Table 1). The majority were male (n = 1659, 56.3%), and evaluated in clinics located in Ontario (n = 1071, 36.3%). A total of 2163 participants (73.3%) presented to the clinic within seven days of their injury (early group), whereas 786 (26.7%) presented 8-28 days after their injury (late group). Those in the early group presented to the clinic 3.12 (± 1.8) days post-injury, versus 14.07 (± 5.5) days in the late group.

A completed baseline assessment was recorded for 1074 (36.4%) of the participants. Participants reported previously diagnosed anxiety (233, 7.9%), depression (80, 2.7%), headache (32, 1.1%), learning disability (149, 5.1%), ADD (47, 1.6%), and ADHD (111, 3.8%). The majority reported no previous SRCs (1816, 61.6%).

Most participants reported no loss of consciousness (n = 2600, 88.2%), no post-traumatic seizure (n = 2871, 97.4%), and no post-traumatic amnesia (n = 2501, 84.8%), but those who did experienced similar rates of anterograde and retrograde amnesia.

Participants had a mean Post-Concussion Symptom Scale (PCSS) score of 26.6 ± 21.66 / 132 and reported an average of 10.03 ± 6.17 / 22 possible symptoms. Most SRCs were sustained playing hockey (n = 1198, 40.6%), followed by soccer (n = 377, 12.8%), football (n = 271, 9.2%), and rugby (n = 192, 6.5%).

Factors associated with early versus late presentation time

Early presentation was associated with being male (OR,

Table 2.
Participant and injury characteristics associated with treatment presentation time from multiple logistic regression model

Characteristic	Odds Ratio	95% Confidence Interval	P Value
Male (Ref = female)	1.24	1.00 – 1.52	.047
Completed Baseline (Ref = no)	2.58	2.10 – 3.18	<.001
Older Age	0.93	0.87 – 0.99	.020
Greater Number of Previous self-reported SRCs	0.83	0.75 – 0.92	<.001
History of Diagnosed Anxiety (Ref = no)	1.04	0.74 – 1.46	.833
History of Diagnosed Depression (Ref = no)	0.90	0.53 – 1.53	.691
History of Diagnosed Headache (Ref = no)	0.92	0.41 – 2.04	.834
History of Diagnosed Learning Disability (Ref = missing)			
No	5.34	3.80 – 7.50	<.001
Yes	4.98	2.99 – 8.31	<.001
History of Diagnosed ADD/ADHD (Ref = none)			
ADD	0.61	0.31 – 1.17	.137
ADHD	0.70	0.44 – 1.09	.110
Loss of Consciousness (Ref = no)			
Unsure	1.17	0.79 – 1.72	.441
Yes	0.94	0.64 – 1.39	.768
Post-Traumatic Amnesia (Ref = retrograde)			
Anterograde	1.06	0.69 – 1.64	.783
None	1.20	0.85 – 1.68	.303
Post-Traumatic Seizures (Ref = no)			
No	0.62	0.27 – 1.41	.252
Yes	0.79	0.25 – 2.56	.696

ADD/ADHD = Attention Deficit Disorder / Attention Deficit Hyperactivity Disorder; Ref = Reference value used in logistic regression; SRCs = Sport Related Concussions; P-values of characteristics with significant associations are bolded. **NOTE**: Non-significant (p >.05) characteristics not reported in the table include – Province, location of impact on the head and body, and sport / mechanism of injury with the exception of Skiing which was the only sport significantly associated with presentation time (OR, 0.39 [95% CI, 0.16 – 0.99]; p<.046).

1.24 [95% CI, 1.00 – 1.52]), completing a pre-injury baseline assessment (OR, 2.58 [95% CI, 2.10 – 3.18]), and responding (vs. not responding) to having a diagnosed learning disability – whether 'yes' (OR, 4.98 [95% CI, 2.99 – 8.30] or 'no' (OR, 5.34 [95% CI, 3.80 – 7.50]) (Table 2).

Older adolescent athletes were less likely to present early (OR, 0.93 [95% CI, 0.87 – 0.99]), as were those who had sustained a greater number of previous SRCs (OR, 0.83 [95% CI, 0.75 – 0.92]). Reports of prior diagnoses of anxiety, depression, headache, or ADD/ADHD were not significantly associated with presentation time. The same was true for reports of loss of consciousness, post-traumatic amnesia, post-traumatic seizure, and location of impact on the head or body. The type of sport being played at the time of injury was also not associated with presentation time, except for snow skiing, which was associated with late presentation (OR, 0.39 [95% CI, 0.16 – 0.99]).

The propensity score classified patients as early vs. late (AUC = 0.71 [95% CI, 0.69 – 0.73]; Hosmer and Lemeshow Goodness-of-Fit $\chi^2 = 5.23$, p = 0.73) (Table 3). Figure 2 presents side-by-side boxplots of early versus late presenters by quintile of propensity score. The plot shows good overlap of distribution of propensity score between early and late presenters indicating the propensity score achieves good balance of covariates between the two groups. Appendix 1 further demonstrates how balance of the included covariates is achieved when stratified across quintiles.

Discussion

We determined baseline patient and injury characteristics associated with time to treatment presentation for SRC among 12-18-year-old athletes seeking care from Canadian concussion clinics. Our propensity score demonstrated modest ability (AUC = 0.71; 95% CI, 0.69 – 0.73) to classify participants as either early or late presenters.

Our results indicated that males were more likely to present to the clinic early compared to females. The association between male sex and early presentation for care was unexpected, as current research suggests that adolescent males are less likely than females to report concussion symptoms[19,20], and generally have more negative perceptions about the consequences of symptom reporting[19]. It is possible that a delay in symptom reporting would result in a later presentation for treatment, but this was not demonstrated in our data. Athletes with a completed baseline assessment were approximately 2.6 times more likely to present early than those without a completed baseline. This finding aligns with our hypothesis, as athletes who have previously established relationships with

Table 3.
Propensity model performance measures

Test			
Overall Model Evaluation	AUC (95% CI)		
	0.71 (0.69 – 0.73)		
Hosmer & Lemeshow Goodness-of-Fit Test	Chi-square	df	P-Value
	5.23	8	.73
AUC = Area under the curve; df = degrees of freedom			

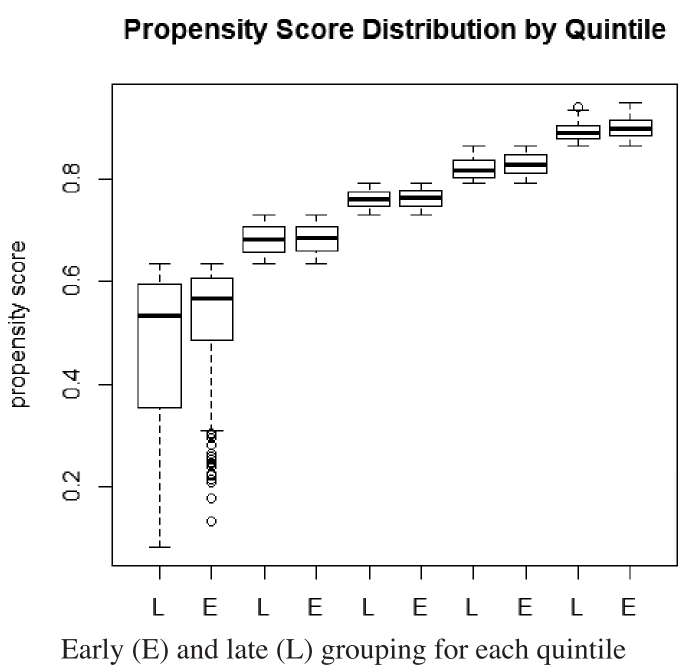

Figure 2.
Propensity score distribution by quintile (Q1-Q5) dichotomized by early (E) or late (L) grouping. Boxes represent the interquartile ranges (25th percentile to 75th percentile) of each quintile for both the early (E) and late (L) groups. Median values are represented by the line in the middle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

a local clinician may also have more readily available access to care compared to those without these pre-existing relationships. Additionally, athletes with recorded data on a previous diagnosis of a learning disability (yes or no) were upwards of five times more likely to present early than those for whom this data was missing. This too, could relate to a previous relationship with the clinic, or prior education from the treating clinician on seeking earlier care.

We found that older athletes were more likely to present late. It is possible that as the competitive culture of sport intensifies in older age groups, older athletes may be less inclined to report concussion related symptoms and seek treatment. Factors that may explain the reduced self-reporting behaviours in older athletes include a fear of reduced playing time, fear of letting down parents, coaches, or teammates, underestimation of the injury severity, a decline in one's athletic identity, or loss of scouting/scholarship opportunities.[4,19,21] A study by Kuroski *et al*.[19] on concussion knowledge and reporting behaviours in 496 high-school athletes found that younger athletes were more likely to self-report SRC symptoms despite older athletes demonstrating greater concussion education and knowledge.[19] We had also hypothesized that athletes who had suffered previous concussions would have a greater odds of presenting early, but this was not observed. It may be that those with previous concussion experience are more familiar with concussion management techniques and therefore opt to self-manage their symptoms in the early stages of recovery. However, this theory has yet to be demonstrated in the literature.

A number of acknowledged negative prognostic factors for recovery from SRC (i.e. a history of a diagnosed anxiety disorder, depression, or headache disorder) and surrogate markers of injury severity (i.e. LOC, PTA, PTS, location of impact on the head/body)[22,23] were not associated with athlete presentation time. Given that early presentation for care may be associated with better clinical outcomes[12,13,24], it is encouraging that mental health issues (anxiety, depression) and headaches do not seem to act as barriers to accessing early treatment. A possible explanation for the lack of association observed may be related to how these questions are asked during the clinical assessment (i.e., previously *diagnosed* anxiety or depression). Athletes may have experienced significant feelings of anxiety or depression but have not been formally diagnosed with a mental health disorder, prompting clinicians to record negative answers when asking about these conditions. Regarding surrogate markers of injury severity, we expected that athletes with these injury characteristics would take longer to access care, as they may be initially directed to emergency departments for assessment. The relationship between surrogate markers of injury severity and clinical recovery is still unclear in adolescent athletes, however, most studies indicate that factors such as LOC and PTA are not strong predictors of clinical outcome.[22,23] Our findings suggest that injury severity characteristics also do not seem to impede athletes from seeking early care.

Given that this is, to our knowledge, one of only two observational studies to develop a propensity score to balance patient characteristics associated with early vs. late care seeking behaviour, there is limited data to which we can compare the performance of our propensity model to. Lawrence *et al*.[13] conducted a smaller observational study of 253 acute (<14 days) concussion cases to see if earlier initiation of exercise influenced return to sport and school/work in athletes aged 15-20 years. The authors used a similar propensity score to stratify participants into quintiles based on nine covariates. The authors provide a supplemental table demonstrating that their propensity score achieves adequate balance of the included covariates when stratified across quintiles. We present similar data in Appendix 1 demonstrating a shift from imbalance between the 'early' and 'late' subjects in the pooled data, to balance between early and late subjects across the five quintiles.

Strengths and limitations

Our study had strengths. It is the first to describe the characteristics of this subpopulation of athletes within the large national database. Consequently, we were able to generate a large sample size (n = 2949). Further, the limiting sample size of our smallest group was 786 (late group) which far exceeded the minimum requirement of 160 estimated during the planning of this study. Recent studies investigating the impact of treatment timing on recovery rates by Kontos *et al*.[12] and Lawrence *et al*.[13] had sample sizes of 416 and 253 participants respectively. The completeness and quality of data provided through the database aided in maximizing our sample size, as only 225 (7.5%) of the retrieved records had missing data inputs.

Also, we included 16 covariates in our model that are associated with health outcomes in people with concussion. Lawrence *et al*.[13] developed a propensity score through multiple logistic regression for time-to-aerobic exercise consisting of nine covariates, and it included symptom severity at presentation to the clinic which may be unfitting since it is likely confounded with time to presentation. Our study captured each of the same covariates plus seven additional factors with the exception of symptom severity. Symptom severity scores for each patient were not included in the multiple logistic regression because they were not recorded at a uniform point in time following injury for each subject.

Our study had limitations. First, despite including a large number of covariates in the development of our propensity score, such scores cannot balance participants within each quintile based on unmeasured covariates. Further, such scores cannot account for bias due to chance to the same degree as true randomization.[15] Thus, there may be other covariates that influence athlete presentation time that our model did not consider, and residual confounding may still be present even after stratification by propensity score. Therefore, our model should first be externally validated in an independent sample of adolescent athletes with SRCs before further comments are made on its generalizability to this population. Second, the possibility of selection bias in favour of the early group should be considered. It is possible that athletes who are more proactive about accessing care may preferentially seek out concussion management clinics, and be more inclined to seek earlier treatment. This may partly explain why significantly more athletes presented early versus late in our study, and may further limit our findings to this specific group of proactive athletes.

Directions for future research

Subsequent investigations should focus on identifying additional patient and/or injury characteristics that may be associated with early care seeking behaviour among adolescent athletes. For instance, a recent study by Eagle *et al*.[25] reported that cognitive, migraine, and fatigue factors assessed via the PCSS were the most robust predictors of prolonged recovery for patients presenting within one week of a SRC, whereas the affective factors were the most robust predictors of prolonged recovery for patients presenting within two-to-three weeks of a SRC. Furthermore, our propensity score should be validated in an independent sample of adolescent athletes. The above recommendations will allow for the development of a more robust propensity score, leading to improved stratification of participants into quintiles, further minimization of residual sample bias, and therefore increased confidence in group similarity before outcome comparisons are made.

Conclusions

This is, to our knowledge, the first study to investigate patient and injury characteristics associated with time to presentation for care for SRCs in 12 to 18-year-old athletes. Being male, having a completed pre-injury baseline assessment, and responding to having a diagnosed learning disorder were associated with early presentation; whereas older age and self-reported previous SRCs were associated with a late presentation. Our propensity score had a modest ability to balance participants based on presentation time. Further patient and injury characteristics should be assessed for inclusion in the propensity score, which then needs to be externally validated before recommending it for use in future research.

Key Points

Question: Which characteristics of adolescent athletes with sport-related concussions (SRC) are associated with 'early' versus 'late' presentation to concussion management clinics for multimodal treatment?

Findings: This is a cohort study that included 2949 participants. Male athletes with a completed baseline assessment are more likely to seek early treatment following a SRC, and older athletes with a greater number of previous SRCs are less likely to present early.

Meaning: Following external validation, our propensity score will be used to examine the impact of treatment timing on adolescent athlete recovery outcomes.

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Appendix 1.
Balance diagnostics for the distribution of covariates on dichotomized early vs. late presentation based on propensity score quintile stratum.

	All (n=2949)					Q1 (n=590)					Q2 (n=590)				
	Early (n = 2163)		Late (n = 786)		χ2	Early (n = 293)		Late (n = 297)		χ2	Early (n = 409)		Late (n = 181)		χ2
	n	%	n	%	p-value	n	%	n	%	p-value	n	%	n	%	p-value
Sex – male	1257	58.1	402	51.2	0.0007	121	41.3	122	41.1	0.9	200	48.9	84	46.1	0.6
Location – Postal Code															
A	224	10.4	71	9.0	0.0001	15	5.1	16	5.4	0.9	37	9.0	19	10.5	0.5
H	46	2.1	22	2.8		10	3.4	10	3.4		12	2.9	8	4.4	
J	125	5.8	66	8.4		38	13.0	33	11.1		41	10.0	24	13.3	
K	140	6.5	62	7.9		25	8.5	33	11.1		45	11	12	6.6	
L	573	26.5	171	21.8		43	14.7	45	15.2		90	22	31	17.1	
M	74	3.4	48	6.1		38	13.0	35	11.8		18	4.4	9	4.9	
N	84	3.9	35	4.5		14	4.8	15	5.1		24	5.9	9	4.9	
P	53	2.5	33	4.2		16	5.5	24	8.1		13	3.2	4	2.2	
S	305	14.1	89	11.3		19	6.5	17	5.7		36	8.8	24	13.3	
T	166	7.7	55	7.0		22	7.5	15	5.1		26	6.4	12	6.6	
V	373	17.2	134	17.1		53	18.1	54	18.2		67	16.4	29	4.9	
Completed Baseline Assessment	911	42.1	163	20.7	<.0001	18	6.1	23	7.7	0.4	18	4.4	11	6.1	0.4
Hx Anxiety	164	7.6	69	8.8	0.3	39	13.3	29	9.8	0.2	33	8.1	13	7.2	0.7
Hx Depression	52	2.4	28	3.6	0.09	22	7.5	14	4.7	0.2	10	2.4	9	5.0	0.1
Hx Headache	21	1.0	11	1.4	0.3	7	2.4	6	2.0	0.8	4	1.0	2	1.1	0.9
Hx Learning Disability															
Yes	106	4.9	43	5.5	0.0001	27	9.2	20	6.7	0.0003	25	6.1	6	3.3	0.05
No	1992	92.1	631	80.3		205	70.0	171	57.6		380	92.9	169	93.4	
Missing	65	3.0	112	14.3		61	20.8	106	35.7		4	1.0	6	3.3	
Hx ADD/ADHD															
ADD	29	1.3	18	2.3	0.09	14	4.8	13	4.4	0.9	3932	0.7	3	1.7	0.6
ADHD	76	3.5	35	4.5		21	7.2	21	7.1		14	3.4	6	3.3	
None	2058	95.2	733	93.3		258	88.1	263	88.6		392	95.8	172	95.0	
Mechanism of Injury															
Basketball	126	5.8	47	6.0	<.0001	13	4.4	17	5.7	0.8	28	6.9	11	6.1	1.0
Cheerleading	55	2.5	24	3.1		10	3.4	13	4.4		14	3.4	7	3.9	
Football	213	9.9	58	7.4		9	3.1	9	3.0		30	7.3	8	4.4	
Hockey	916	42.4	282	35.9		77	26.3	82	27.6		134	32.8	63	34.8	
Lacrosse	86	4.0	19	2.4		1	0.3	3	1.0		7	1.7	3	1.7	
Martial Arts	39	1.8	24	3.1		17	5.8	12	4.0		11	2.7	8	4.4	
Other	156	7.2	85	10.8		43	14.7	55	18.5		46	11.3	18	9.9	
Ringette	50	2.3	17	2.2		4	1.4	4	1.4		12	2.9	6	3.3	
Rugby	128	5.9	64	8.1		46	15.7	32	10.8		37	9.1	20	11.1	
Skiing	59	2.7	41	5.2		32	10.9	29	9.8		9	2.2	3	1.7	
Soccer	275	12.7	102	13.0		35	12.0	35	11.8		66	16.1	27	14.9	
Volleyball	60	2.8	23	2.9		6	2.1	6	2.0		15	3.7	7	3.9	

ADD/ADHD = Attention Deficit Disorder / Attention Deficit Hyperactivity Disorder; Hx = History; L = Left; LOC = Loss of Consciousness; n = number; PTA = Post Traumatic Amnesia; PTS = Post Traumatic Seisure; Q1-5 = Quintile 1 through to 5; R = Right; SD = Standard Deviation; SRC(s) = Sport Related Concussion(s); t-test = Two-sided t-test or chi-square (χ^2); = Mean.

	All (n=2949)					Q1 (n=590)					Q2 (n=590)				
	Early (n = 2163)		Late (n = 786)		$\chi 2$	Early (n = 293)		Late (n = 297)		$\chi 2$	Early (n = 409)		Late (n = 181)		$\chi 2$
	n	%	n	%	p-value	n	%	n	%	p-value	n	%	n	%	p-value
Location of Impact – Body															
front	191	8.8	79	10.1	0.3	36	12.3	39	13.1	0.8	47	11.5	14	7.7	0.2
rear	218	10.1	62	7.9	0.07	21	7.2	12	4.0	0.1	28	6.9	16	8.8	0.4
left	130	6.0	36	4.6	0.1	9	3.1	10	3.4	0.8	12	2.9	8	4.4	0.4
right	143	6.6	52	6.6	1.0	20	6.8	17	5.7	0.6	24	5.9	14	7.7	0.4
Location of Impact – Head															
crown	28	1.3	12	1.5	0.6	5	1.7	6	2.0	0.8	11	2.7	3	1.7	0.4
L frontal	436	20.2	164	20.9	0.7	55	18.8	66	22.2	0.3	85	20.8	37	20.4	0.9
L parietal	97	4.5	45	5.7	0.2	21	7.2	27	9.1	0.4	22	5.4	7	3.9	0.4
L temporal	258	11.9	90	11.5	0.7	29	9.9	34	11.5	0.5	51	12.5	19	10.5	0.5
L occipital	468	21.6	145	18.45	0.06	41	14.0	43	14.5	0.9	69	16.9	33	18.2	0.7
R frontal	545	25.2	199	25.3	0.9	72	24.6	77	25.9	0.7	93	22.7	44	24.3	0.7
R parietal	130	6.0	51	6.5	0.6	20	6.8	19	6.4	0.8	29	7.1	10	5.5	0.5
R temporal	265	12.3	92	11.7	0.7	36	12.3	28	9.4	0.3	51	12.5	23	12.7	0.9
R occipital	492	22.8	162	20.6	0.2	50	17.1	50	16.8	0.9	90	22	36	19.9	0.6
LOC															
Yes	115	5.3	55	7	0.17	24	8.2	29	9.8	0.6	25	6.1	10	5.5	0.96
No	1912	88.4	688	87.5		252	86.0	255	85.9		362	88.5	161	88.9	
Unsure	136	6.3	43	5.5		17	5.8	13	4.4		22	5.4	10	5.5	
Post Traumatic Amnesia															
None	1851	85.6	650	82.7	0.15	234	79.9	229	77.1	0.7	347	84.8	153	84.5	0.6
Anterograde	162	7.5	69	8.8		29	9.9	32	10.8		36	8.8	13	7.2	
Retrograde	150	6.9	67	8.5		30	10.2	36	12.1		26	6.4	15	8.3	
PTS															
Yes	24	1.1	9.0	1.2	0.6	3	1.0	3	1.0	0.9	4	0.98	3	1.7	0.8
No	2103	97.2	768	97.7		286	97.6	290	97.6		402	98.3	177	97.8	
Missing	36	1.67	9	1.2		4	1.4	4	1.4		3	0.73	1	0.55	
	$\bar{X}$	SD	$\bar{X}$	SD	t-test p-value	$\bar{X}$	SD	$\bar{X}$	SD	t-test p-value	$\bar{X}$	SD	$\bar{X}$	SD	t-test p-value
Age	15.8	1.5	16.1	1.5	<.0001	16.4	1.3	16.4	1.4	0.9	16.0	1.4	16.2	1.4	0.1
Number of Previous SRC	0.6	0.9	0.7	1.2	.0005	1.0	1.3	1.1	1.5	0.5	0.69	0.97	0.57	0.9	0.1

ADD/ADHD = Attention Deficit Disorder / Attention Deficit Hyperactivity Disorder; Hx = History; L = Left; LOC = Loss of Consciousness; n = number; PTA = Post Traumatic Amnesia; PTS = Post Traumatic Seisure; Q1-5 = Quintile 1 through to 5; R = Right; SD = Standard Deviation; SRC(s) = Sport Related Concussion(s); t-test = Two-sided t-test or chi-square (χ^2); = Mean.

	Q3 (n=590)					Q4 (n=590)					Q5 (n=589)				
	Early (n = 438)		Late (n = 152)		χ^2	Early (n = 492)		Late (n = 98)		χ^2	Early (n = 531)		Late (n = 58)		χ^2
	n	%	n	%	p-value	n	%	n	%	p-value	n	%	n	%	p-value
Sex – male	253	57.8	89	58.6	0.9	307	62.4	62	63.3	0.9	376.	70.8	45	77.6	0.3
Location – Postal Code															
A	62	14.2	19	12.5	0.8	58	11.8	12	12.2	0.7	52	9.8	5	8.6	0.9
H	5	1.1	3	1.8		13	2.6	1	1.0		6	1.1	0	0	
J	19	4.3	3	2.0		22	4.5	5	5.1		5	0.9	1	1.7	
K	22	5.0	8	5.3		20	4.1	5	5.1		28	5.3	4	6.9	
L	141	32.2	48	31.6		27	27.5	120	24.4		179	33.7	20	34.5	
M	2	0.5	2	1.3		15	3.1	2.0	2.0		1	0.2	0	0	
N	20	4.6	5	3.3		10	2.1	2.0	2.0		16	3.0	4	6.9	
P	6	1.4	3	2.0		16	3.3	2	2.0		2	0.4	0	0	
S	77	17.6	24	15.8		85	17.3	15	15.3		88	16.6	9	15.5	
T	36	8.2	14	9.2		27	5.5	11	11.2		55	10.4	3	5.2	
V	48	11	23	15.1		106	21.5	16	16.3		99	18.6	12	20.7	
Completed Baseline Assessment	49	11.2	20	13.2	0.5	295	60.0	52	53.1	0.2	531	100	57	98.3	0.003
Hx Anxiety	33	7.5	19	12.5	0.06	31	6.3	7	7.1	0.8	28	5.3	1	1.7	0.2
Hx Depression	9	2.1	3	2.0	1.0	6	1.2	2	2.0	0.5	5	0.9	0	0	0.5
Hx Headache	4	0.9	3	2.0	0.3	5	1.0	0	0	0.3	1	0.2	0	0	0.7
Hx Learning Disability															
Yes	15	3.4	7	4.6	0.5	24	4.9	6	6.1	0.6	15	2.8	4	6.9	0.1
No	423	96.6	145	95.4		468		95.1	92	93.9		516	97.2	54	93
Missing	0	0	0	0		0	0	0	0		0	0	0	0	
Hx ADD/ADHD															
ADD	5	1.1	2	1.3	0.8	5	1.0	0	0	0.6	2	0.4	0	0	0.9
ADHD	17	3.9	4	2.6		13	2.6	3	3.1		11	2.1	1	1.7	
None	416	95	146	96		474	96.3	95	96.9		518	97.6	57	98.3	
Mechanism of Injury															
Basketball	36	8.2	14	9.2	0.8	26	5.3	2	2.0	0.5	23	4.3	3	5.2	0.4
Cheerleading	4	0.9	0	0		25	5.1	4	4.1		2	0.4	0	0	
Football	52	11.9	13	8.6		62	12.6	18	18.4		60	11.3	10	17.2	
Hockey	196	44.8	64	42.1		198	49.2	38	38.8		311	58.6	35	60.3	
Lacrosse	13	3.0	7	4.6		26	5.3	2	2.0		39	7.3	4	6.9	
Martial Arts	4	0.9	2	1.3		5	1.0	2	2.0		2	0.6	1	1.7	
Other	15	3.4	6	4.0		31	6.3	4	4.1		21	3.4	2	3.5	
Ringette	14	3.2	4	2.6		8	1.6	1	1.0		12	2.3	2	3.5	
Rugby	12	2.7	3	2.0		32	6.5	8	8.2		1	0.2	1	1.7	
Skiing	13	3.0	9	5.9		4	0.8	0	0		1	0.2	0	0	
Soccer	60	13.7	22	14.5		64	13	18	18.4		50	9.4	0	0	
Volleyball	19	4.3	8	5.3		11	2.2	1	1.0		9	1.7	1	1.7	

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	Q3 (n=590)					Q4 (n=590)					Q5 (n=589)				
	Early (n = 438)		Late (n = 152)		χ^2	Early (n = 492)		Late (n = 98)		χ^2	Early (n = 531)		Late (n = 58)		χ^2
	n	%	n	%	p-value	n	%	n	%	p-value	n	%	n	%	p-value
Location of Impact – Body															
front	32	7.3	11	7.2	1.0	34	5.8	9	9.2	0.4	42	7.9	6	10.3	0.5
rear	48	11	16	10.5	0.9	50	10.2	8	8.2	0.5	71	13.4	10	17.2	0.4
left	27	6.2	8	5.3	0.7	31	6.3	5	5.1	0.7	51	9.6	5	8.6	0.8
right	21	4.8	12	7.9	0.2	40	8.1	5	5.1	0.3	38	7.1	4	6.9	0.9
Location of Impact – Head															
crown	3	0.71	1	0.7	0.1	5	1.0	1.0	1.0	1.0	4	0.8	1	1.7	0.4
L frontal	99	22.6	29	19.1	0.4	103	20.9	14	14.3	0.1	94	17.7	18	31.0	0.01
L parietal	16	3.7	4	2.6	0.5	20	4.1	4	4.1	1.0	18	3.4	3	5.2	0.5
L temporal	51	11.6	18	11.8	0.9	53	10.8	12	12.2	0.7	74	13.9	7	12.1	0.7
L occipital	103	23.5	34	22.4	0.8	116	23.6	23	23.5	1.0	139	26.2	12	20.7	0.4
R frontal	119	27.2	40	26.3	0.8	131	26.6	19	19.4	0.1	130	24.5	19	32.8	0.2
R parietal	23	5.3	12	7.9	0.2	32	6.5	6	6.1	0.9	26	4.9	4	6.9	0.5
R temporal	49	11.2	23	15.1	0.2	57	11.6	10	10.2	0.7	72	13.6	8	13.8	0.1
R occipital	111	25.3	34	22.4	0.5	104	21.1	29	29.6	0.07	137	25.8	13	22.4	0.6
LOC															
Yes	32	7.3	10	6.6	0.7	14	2.9	3	3.1	0.8	20	3.4	3	5.2	0.6
No	389	88.8	134	88.2		443	90.0	86	87.8		466	87.8	52	89.7	
Unsure	17	3.9	8	5.3		35	7.1	9	9.1		45	8.5	3	6.2	
Post Traumatic Amnesia (PTA)															
None	367	83.8	132	86.8	0.6	430	87.4	84	85.7	0.6	473	89.1	52	89.7	0.5
Anterograde	37	8.5	11	7.2		27	5.5	8	8.2		33	6.2	5	8.6	
Retrograde	34	7.8	9	5.9		35	7.1	6	6.1	25	4.2	1	1.7		
Post Traumatic Seisure (PTS)															
Yes	5	1.1	1	0.7	0.5	7	1.4	0	0	0.09	5	0.9	2	3.5	0.2
No	430	98.2	151	99.3		481	97.8	95	96.9		504	94.9	55	94.8	
Missing	3	0.7	0	0		4	0.8	3	3.1		22	4.1	1	1.7	
	$\bar{X}$	SD	$\bar{X}$	SD	t-test p-value	$\bar{X}$	SD	$\bar{X}$	SD	t-test p-value	$\bar{X}$	SD	$\bar{X}$	SD	t-test p-value
Age	15.8	1.4	15.5	1.6	0.07	15.6	1.6	15.8	1.4	0.3	15.5	1.4	15.6	1.2	0.6
Number of Previous SRC	0.4	0.8	0.5	0.8	0.4	0.6	0.9	0.5	0.9	0.6	0.4	0.6	0.6	0.8	0.02

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