Factors Associated with Loss to Follow-Up in Pediatric Concussion Patients after Initial Visit: A Retrospective Study at a Concussion Clinic

Emilia Núñez-Peña, MD[1], Ryan P. Kelly, BS[2], Santiago Campos, MD[3], Maria C. Diaz, MD[4,5], Pamela A. Castillo, MD[3], Shivangi Kataria, MSAB[5], Alexia M. Perez, MD[4,5], Maria Dolores Beletanga, MD[4,5], and Alcy R. Torres, MD[4,5]

Objective The objective of this retrospective study is to identify factors associated with loss to follow-up for postconcussion clearance in pediatric patients by comparing loss to follow-up and full clearance patients.

Study design This retrospective single-center cohort study analyzed 140 consecutive patients at a pediatric concussion clinic of a safety-net hospital for loss to follow-up, defined as not achieving clearance at last appointment. Univariate and multivariate regression models were fit on variables of interest, including demographic, mechanism and severity of concussion, and characteristics of the first evaluation postconcussion and follow-up management.

Results Of the sample, 40% (n = 56) achieved clearance and 60% (n = 84) were lost to follow-up. Median age was 15 (IQR 11-17), with male predominance (60.7%). Living with a biological parent (OR = 0.145, 95% CI = 0.028-0.760) and sports involvement (OR = 0.256, 95% CI = 0.092-0.764) were protective factors, while being 10 years old or older (OR = 13.466, 95% CI = 2.792-64.958) and attending 2 or fewer follow-up appointments (OR = 19.027, 95% CI = 4.991-72.533) were risk factors for loss to follow-up. No significant differences were found between sex, race, driving distance, type of insurance, and mechanism of injury.

Conclusions Living with a biological parent and involvement in sports showed to be protective factors for loss to follow-up. Age at time of concussion and number of appointments were risk factors. A "golden window" of 2 appointments was identified, highlighting the need of a strong rapport and engagement in shared decision-making. Future directions include prospective studies implementing strategies targeting adolescents and building a strong patient-provider relationship. *(J Pediatr 2024;14:200131)*.

Pediatric traumatic brain injuries, including concussions, continue to be a growing public health concern.[1,2] According to reports, the annual incidence of sports and recreational activity-related mild traumatic brain injuries (mTBIs), better known as concussions, ranges between 1.1 and 1.9 million in those under the age of 18 in the US.[3] In contrast to most nonsevere acute traumatic injuries in pediatric patients, concussions have 3 key distinctive features. First, patients with mTBI may not only seek initial medical evaluation in the emergency department, but also in primary pediatrician offices, urgent care facilities, and specialty care clinics.[4-7] Secondly, mTBIs have a variety of clinical sequelae encompassing neurological, musculoskeletal, endocrinological, and psychiatric manifestations, which may progress to a chronic condition with a complex pattern of evolution.[6,8-15] Lastly, due to the characteristics of the developing brain, prolonged follow-up is often necessary to ensure the best possible long-term clinical outcomes for pediatric patients.[6,16-21]

Although most pediatric patients will go on to completely recover within 4 weeks following injury, 15%-30% will develop persisting symptoms for longer than 3 months.[14,22] In consequence, patients that require prolonged postconcussion follow-up care, are usually the ones with the highest burden of symptoms, risk factors for poor outcomes and/or comorbidities.[23]

Current pediatric mTBI management guidelines among international institutions vary on their recommendations. The Centers for Disease Control and Prevention does not give any definite recommendation about a first follow-up visit after a concussion, mainly due to the lack of randomized control trials that prove its benefit.[24] In contrast, the Ontario Neurotrauma Foundation recommends a first follow-up visit 1-2 weeks after initial injury for all pediatric patients.[16] Plus, the Ontario Neurotrauma Foundation also encourages further appointments depending on the presence of postconcussive symptoms and of factors associated with poor prognosis (Hispanic ethnicity; premorbid conditions such as neurological/psychiatric problems, learning difficulties, and behavioral problems; older age; female biological sex; prior concussions; socioeconomic status; family history of migraines or psychiatric conditions; and early postconcussive symptoms).[16] Overall, the consensus is that follow-up care after a concussion should be strictly individualized to the patient, and that a patient

BMC	Boston Medical Center
EMR	Electronic medical record
mTBIs	Mild traumatic brain injury

From the [1]Tecnológico de Monterrey, School of Medicine and Health Sciences, Monterrey, Nuevo Leon, Mexico; [2]Larner College of Medicine at the University of Vermont, Burlington, VT; [3]Department of Pediatrics, Nicklaus Children's Hospital, Miami, FL; [4]Department of Pediatrics, Boston University Chobanian and Avedisian School of Medicine, Boston, MA; and [5]Department of Biostatistics, Biometrics FSP 360, Syneos Health, Morrisville, NC

https://doi.org/10.1016/j.jpedcp.2024.200131

should not be considered medically cleared for regular physical and cognitive activities until return to neurological baseline occurs.[16,23,25,26]

Research focused on pediatric mTBI follow-up trends is not lacking, but almost all have as primary outcome attending a first follow-up visit.[27-34] Ramsay et al (2023) recently published a literature review on this subject.[28] Of the 22 articles reviewed, none focused on identifying factors that influenced completion of postconcussion follow-up until achieving full clearance for contact activities.[28] Not included in this review is a large longitudinal study based in Ontario focused on identifying factors associated with follow-up care for pediatric mTBI patients, in which follow-up care was defined as having attended at least one follow-up visit after the injury.[27] To our knowledge, only 1 study has evaluated clinical data for factors associated follow-up appointment adherence until full medical clearance in pediatric postconcussion management.[35] Nevertheless, their definition for clearance was broad and only few factors were analyzed.[35]

Despite concussions being a common, ubiquitous, and comorbid pediatric injury, many aspects regarding long-term management, including factors contributing to the success or lack thereof of follow-up at concussion clinics, remain uncertain. Hypotheses-generating studies are needed before interventions to reduce patient loss to follow-up can be designed and implemented. Which in consequence, will help build a strong foundation for future evidence-based guidelines on management of mTBIs in the pediatric population.

The objective of this study is to identify factors associated with loss to follow-up for concussion management in the pediatric patients who have attended at least 1 follow-up visit by retrospectively comparing 2 study groups: lost to follow-up and full clearance patients. These patients have already received acute care, a referral to a concussion clinic, and have already attended at least 1 visit. The present study is the first to evaluate loss of follow-up and full clearance in patients who have already attended an initial visit to a concussion clinic.

Methods

Study Design and Setting

In this retrospective single-center cohort study, all patients included were evaluated and treated at the concussion clinic of the pediatric neurology department at Boston Medical Center (BMC), a safety-net hospital. A safety-net hospital is defined as one having a high degree of medical care services provided to patients who are uninsured or utilize Medicaid insurance.[36] The concussion clinic only sees patients directly referred to the clinic by other providers or are previous patients of the pediatric neurology department at BMC. At every appointment, patients have a comprehensive neurological and cognitive evaluation and are surveyed for number and severity of postconcussion symptoms. If the patient continues to be symptomatic, has not returned to neurological baseline, or has risk factors for poor prognosis, a follow-up appointment is scheduled in 1-2 weeks. To collect data, electronic medical records (EMR) of 241 consecutive concussion clinic patients from 2013 to 2021 were reviewed.

Ethics and Safety

The study was conducted in accordance with the Declaration of Helsinki. The Institutional Review Board of BMC approved the study protocol (H-38768), including data management. Informed consent was waived due to research being deemed of no risk.

Patient Selection and Data Collection

Patients selected for the study were between 1 and 21 years old and were evaluated by the concussion clinic at BMC. Participants chosen had concussion or postconcussion symptoms as a main concern for the visit and were scheduled for more than one follow-up appointment due to the presence of postconcussion symptoms and/or poor prognosis factors. The inclusion criteria included a diagnosis of concussion and/or postconcussive syndrome recorded in clinical notes from the first follow-up visit, attending at least 1 follow-up appointment, and either achieving full clearance to return to regular activities (including contact sports) or were lost to follow-up before any clearance was given. For a patient to count as having full clearance, the physician's notes from the last recorded appointment had to textually refer it. Of note, if one patient had another concussion event followed up by the concussion clinic after the complete resolution of a prior concussion, this was counted as an additional case. Exclusion criteria included: achieving partial but not full clearance (ie, aerobic clearance), patient referral to the clinic but no attendance to any follow-up visit, and those whose medical information was recorded predominantly in physical medical records, without a high degree of transference to the EMR.

Once cases were selected an EMR review was done. Five reviewers performed data extraction. Data were collected directly from Epic chart reviews after standardization of operational definitions between members of the data extraction and analysis team (**Table I**). Race and ethnicity were self-reported. Variables were also prespecified by the data extraction and analysis team. These particular variables were selected because they were deemed causal within our conceptual framework. Approved members had signed H-38768 BMC Individual Investigator Agreements. Data were managed using Excel through Box, which is compliant with Health Insurance Portability and Accountability Act and approved by the institution's Institutional Review Board.

After exclusion, 140 cases remained for statistical analysis: 58 in the full clearance group and 88 in the lost to follow-up group. From the 95 excluded patients, 63 had clearance only for aerobic exercise and 4 patients did not attend any appointments. Four patients had a history of head injury that was never diagnosed as a concussion. Three patients presented with unrelated neurological problems. Additionally, 21 patients had information regarding concussion events

Table I. Operational definitions

Mild traumatic brain injuries	"An acute brain injury resulting from mechanical energy to the head from external physical forces including: (1) 1 or more of the following: confusion or disorientation, loss of consciousness for 30 min or less, post-traumatic amnesia for less than 24 h, and/or other transient neurological abnormalities such as focal signs, symptoms, or seizure; (2) Glasgow Coma Scale score of 13-15 after 30 min postinjury or later upon presentation for health care.[37]"
Concussion clinic	Refers to the Boston Medical Center (safety-net hospital) pediatric neurology specialty clinic that focuses on patients with postconcussion, with or without postconcussive complications.
Concussion event	Refers to the individual mTBI episode recorded on EMRs that was followed by a presentation to the concussion clinic.
Clinical signs	Concussion event that clinically manifested with loss of consciousness regardless of duration, anterograde amnesia, retrograde amnesia, and/or confusion (defined as disorientation to time, place, and/or person)[38]
Lost to follow-up subgroup	Patients with postconcussion who on their last recorded concussion clinic appointment the recommendation provided by the medical professional was not full clearance.
Full clearance subgroup	Patients with postconcussion who, according to their last concussion clinic appointment, successfully completed return to play protocol with clearance to physical activities including contact sports by a medical professional.
Clearance for aerobic exercise	Patients with postconcussion who were lost to follow-up after only being cleared for aerobic exercise and not reaching full clearance for contact sports by a medical professional of the concussion clinic.
First evaluation	First medical attention that the patient sought after a concussion event regardless of setting.
Second hit	A second head injury/impact happens in the following 7 d after the first impact and/or while a patient is still symptomatic from a previous concussion. This head impact exacerbates previous postconcussive symptoms and/or the addition of symptoms.
Severe mechanism of injury	Motor vehicle collision with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by motorized vehicle, falls from a height (>3 feet for <2 y of age, and >5 feet for ≥2 y of age); fall from stairs, or head struck by high impact object.[39]
Full-contact sports	Basketball, soccer, boxing, cheerleading, diving, field hockey, ice hockey, lacrosse, martial arts, rodeo, rugby, downhill skiing, ski jumping, snowboarding, team handball, ultimate frisbee, water polo, wrestling, extreme sports*, gymnastics, football (with tackle).[40]
Limited-contact sports	Adventure racing†, baseball, bicycling, canoeing or kayaking (white water), fencing, field events (high jump, pole vault), floor hockey, football (flag or touch), horseback riding, racquetball, skating (ice, in-line, roller), skiing (cross-country, water), skateboarding, softball, squash, volleyball, weightlifting, windsurfing, or surfing.[40]
Formal athlete	A patient who participates in formal sports competitions and has an established training schedule for such sports.
Casual/recreational player	A patient who plays sports in no formal competitions and does not have an established training schedule for such sports.

*Extreme sports definition continues to be controversial, but for the sake of this study includes base jumping, drag racing, hand gliding, motorcycle racing, mountain climbing, grand prix racing, and scuba diving.[41]
†Adventure racing is defined as a combination of 2 or more disciplines, including orienteering and navigation, cross-country running, mountain biking, paddling, and climbing and rope skills.[40]

Table II. Baseline demographic characteristics of pediatric postconcussion patients followed by concussion clinic (n = 140)

Characteristics	Total n = 140 (%)*
Age (per y)	15 (IQR 11-17)
Male sex (ref = female)	85 (60.7)
Race	
White	36 (25.7)
Black	45 (32.1)
Native American	2 (1.4)
Asian	3 (2.1)
Hispanic/Latino	39 (27.9)
Not reported	40 (28.6)
Primary/preferred language	
English	122 (87.7)
Not English	17 (12.1)
Income per zip code	$71,574 (IQR $61 180-$96 414)
Miles to Boston Medical Center (straight line)	5.67 (IQR 2.83-18.6)
Miles to Boston Medical Center (driving)	7.5 (IQR 3.9-24.45)
Living status	
Living with at least 1 biological parent	93 (66.4)
Parental marital status	
Cohabitating or married	41 (29.3)
Separated or divorced	27 (19.3)
Insurance—primary coverage public	36 (25.7)
Education level at time of concussion	
Infant (before preschool)	5 (3.6)
Preschool/kindergarten	2 (1.4)
Elementary (1st-4th grade)	23 (16.4)
Middle school (5th-8th grade)	29 (20.7)
Highschool (9th-12th grade)	67 (47.9)
College/higher education	13 (9.3)
Involved in sports	70 (50)
American football	23 (33.3)
Basketball	18 (26.1)
Soccer	9 (13)
Others	20 (27.6)
Formal athlete (vs casual player)	44 (62.9)
Type of main sport played	
No contact	5 (7.2)
Limited contact	42 (60.9)
Full contact	22 (31.9)
History of concussion	
No history of concussion	92 (65.7)
History of at least 1 previous concussion	45 (32.1)
History of at least 1 concussion with signs	18 (12.8)
History of at least 1 with LOC	8 (5.7)
History of at least 1 with confusion	6 (4.3)
History of at least 1 with anterograde amnesia	4 (2.8)
History of at least 1 with retrograde amnesia	0 (0)

LOC, loss of consciousness.
*Presented as n (%) unless otherwise specified as median (IQR).

recorded mainly in physical medical records without enough in the electronic records to ensure reliability. Of note, 10 patients had 2 separate concussion events, and 1 patient had 3 separate concussion events, in these cases only the first concussion event was included in the analysis to avoid clustering.

Statistical Analysis

Statistical analysis was carried out using IBM SPSS, version 25 (IBM Inc). Descriptive statistics were used to compare

Table III. Characteristics of concussion event of pediatric postconcussion patients followed by concussion clinic

Characteristics	Total n = 140 (%)*	Full clearance n = 56 (%)*	Lost to follow-up n = 84 (%)*
Sport-related concussion (patient actively playing)	40 (28.6)	20 (35.1)	20 (24.1)
Presence of a second hit	33 (23.9)	12 (21.4)	21 (25.6)
Mechanism of injury			
Severe	44 (31.9)	18 (31.6)	26 (32.1)
Ground-level fall	39 (28.3)	14 (24.6)	25 (30.9)
Involving a motor vehicle	31 (22.5)	15 (26.3)	16 (19.8)

*Presented as n (%) unless otherwise specified as median (IQR).

demographic and concussion event information between full clearance and loss to follow-up subgroups. All variables were evaluated against the dependent variable of "Loss to Follow-up" using binary logistic regression to determine statistically significant risk and protective factors for loss to follow-up. All models were univariate unless otherwise specified. Multivariate logistic regression was subsequently used for modeling statistically significant variables influencing loss to follow-up. No post hoc hypothesis testing was done. To minimize the complexity of the model and mitigate collinearity, variable selection was applied using backward stepwise regression, for variables with a P value <.1. Significance was defined as a 2-tailed $P < .05$ and a CI of 95%.

For evaluation of environmental-related factors for loss to follow-up while maintaining the anonymity of information, zip codes were used. Zip code information from the online US Census Bureau portal was used to determine average income per zip code. The driving distance between individual zip codes and BMC was measured using Google Maps.

Results

Characteristics of the Cohort Study

Table II describes the complete demographic characteristics of the total sample (n = 140), where 40% (n = 56) achieved full clearance, and 60% (n = 84) were lost to follow-up. The median age of the total sample population was 15 years old, with a higher male proportion (60.7%). Regarding race, Black patients made up 32% of the sample and White patients 26%. For ethnicity, Hispanic/Latino patients made up 28% of the sample. Primary coverage insurance at the time of concussion consisted of 74% private insurance and 26% public insurance. For the living status of the patient at the time of concussion, 66% lived with at least 1 biological parent. Regarding involvement in sports, 50% of patients were actively involved. Of these patients, most played a limited-contact sport (61%) and 32% played a full-contact sport. The most frequent sports in our sample were American football (33%), basketball, (26%) and soccer (13%). As for prior injuries, 32% had a history of at least 1 previous concussion. Of these, almost 13% manifested clinical signs on at least one of these prior concussions.

Table IV. Characteristics of first evaluation and follow-up by concussion clinic of pediatric postconcussion patients followed by concussion clinic (n = 140)

Characteristics	Total n = 140 (%)*	Full clearance n = 56 (%)*	Lost to follow-up n = 84 (%)*
Time in d to first evaluation	0 (IQR 0-4)	0 (IQR 0-2)	0 (IQR 0-5)
First evaluation location			
Emergency room (ER)/ urgent care	100 (72.5)	41 (72)	59 (72.8)
Primary care physician	19 (13.7)	9 (15.8)	10 (12.2)
Pediatric neurologist outpatient	17 (12.3)	5 (8.8)	12 (14.8)
Imaging was ordered at the first evaluation location	52 (37.7)	17 (30.4)	35 (42.7)
Time in d from concussion event to first visit at concussion clinic	19 (IQR 8-39)	18 (IQR 8-37)	22 (IQR 6-49)
Imaging ordered during follow-up	66 (47.1)	24 (42.1)	42 (50.6)
Number of follow-up appointments	4 (IQR 2-6)	5 (IQR 4-8)	3 (IQR 2-5)
Number of appointments in person	3 (IQR 2-5)	5 (IQR 3-7)	2 (IQR 1-4)
Number of telemedicine appointments	0 (IQR 0-0)	0 (IQR 0-1)	0 (IQR 0-1)
One or more referrals to other specialties during follow-up	86 (61.4)	32 (56.1)	54 (65.1)

*Presented as n (%) unless otherwise specified as median (IQR).

Table III describes the concussion event characteristics of both groups and the total sample. From the total sample, 32% had a severe mechanism of injury and a ground-level fall was the mechanism of injury in 28%. Table IV describes characteristics of first evaluation and follow-up management. Time in days from concussion event to first evaluation had a median of 0 days, meaning most sought care on the same day as the accident. The location of first evaluation was an emergency department or urgent care facility in 72.5% of cases. Median time between concussion event and first concussion clinic appointment was 19 days. For fully cleared patients, the median number of total appointments at the concussion clinic regardless of in-person or telemedicine modality was 5 appointments.

Protective Factors for Loss to Follow-Up

The results of the statistical analysis revealed several protective factors associated with a decreased risk of loss to follow-up after a concussion. In the univariate model, living with at least 1 biological parent was found to be a significant protective factor, reducing the risk of loss to follow-up by 84.5% (OR = 0.155, 95% CI = 0.034-0.716). Involvement in sports showed an OR = 0.518 (95% CI = 0.216-1.027), with a P value <.1 it moved forward to the multivariate analysis.

Table V. Assessment of protective and risk factors for loss to follow-up among pediatric patients receiving postconcussion follow-up

Variables	Univariate OR (95% CI), all (n = 140)	Multivariate OR (95% CI), all
Age 10 y old or older	2.849 (1.184-6.853)	13.466 (2.792-64.958)
Female sex (ref = male)	1.532 (0.750-3.089)	
Race not White (ref = White)	0.818 (0.356-1.881)	
Ethnicity—Hispanic/Latino	1.185 (0.552-2.544)	
Primary/preferred language not English	0.439 (0.156-1.232)	
Income per zip code	1.00 (1.00-1.00)	
Miles to Boston Medical Center (straight line)	0.998 (0.977-1.020)	
Miles to Boston Medical Center (driving)	0.999 (0.982-1.016)	
Living with at least 1 biological parent	0.155 (0.034-0.716)	0.145 (0.028-0.760)
Parental marital status (ref = separated/ divorced) cohabitating or married	1.654 (0.624-4.383)	
Insurance		
Primary coverage public	1.111 (0.509-2.424)	
Had secondary coverage	1.290 (0.523-3.181)	
Involved in sports	0.518 (0.261-1.027)	0.265 (0.092-0.764)
Plays American football (ref = not involved in sports)	0.439 (0.169-1.144)	
Plays basketball (ref = not involved in sports)	0.479 (0.168-1.368)	
Plays soccer (ref = not involved in sports)	0.240 (0.055-1.044)	
Formal athlete (vs casual player)	0.521 (0.194-1.399)	
Type of main sport played—full contact (ref: limited contact)	1.641 (0.589-4.575)	
History of at least 1 previous concussion	0.613 (0.298 – 1.261)	
History of at least 1 with LOC	2.250 (0.437-11.585)	
History of at least 1 with confusion	0.000 (0.000-0.000)	
History of at least 1 with anterograde amnesia	0.229 (0.023-2.266)	
Sport-related concussion (patient actively playing)	0.587 (0.280-1.232)	
Presence of a second hit	1.262 (0.563-2.833)	
Mechanism of injury		
Severe	1.024 (0.495-2.120)	
Ground-level fall	1.371 (0.638-2.948)	
Involving a motor vehicle regardless of severity	0.689 (0.308-1.540)	
Time in d to the first evaluation	1.006 (0.995-1.018)	
First evaluation location (ref = outpatient*)		
Emergency room/urgent care	0.850 (0.409-1.767)	
Imaging was ordered at the first evaluation location	1.708 (0.883-3.504)	
Time in d from first evaluation to first visit at concussion clinic	1.005 (0.998-1.013)	
Time in d from concussion event to first visit at concussion clinic	1.007 (1.000-1.014)	
Imaging was ordered during the follow-up	1.409 (0.714-2.779)	
Number of follow-up appointments		
2 or less appointments in person (ref = 3 or more)	6.910 (2.916-16.375)	19.027 (4.991-72.533)
One or more referrals to other specialties during follow-up	1.455 (0.729-2.903)	

LOC, loss of consciousness.
*Outpatient = Including primary care physician and pediatric neurologist visits.

On the multivariate model, living with at least one biological parent (OR = 0.145, 95% CI = 0.028-0.760), and being involved in sports (OR = 0.256, 95% CI = 0.092-0.764) were statistically significant protective factors for loss to follow-up, reducing the risk for loss to follow-up by 85.5% and 74.4%, respectively. The latter was even when controlling for age at the time at concussion, attendance to 2 or fewer follow-up appointments, and for each other. Table V shows the complete results of the univariate and multivariate analyses.

Risk Factors for Loss to Follow-Up

The results of the statistical analysis revealed several risk factors associated with loss of follow-up. In the univariate model, being 10 years old or older (period of adolescence) at the time of the concussion event was associated with a 3-fold increase in risk for loss to follow-up (OR = 2.849, 95% CI = 1.184-6.853).[42] Having attended only 1 (OR = 7.083, 95% CI = 1.568-32.008) or 2 (OR = 3.006, 95% CI = 1.155-8.138) follow-up appointments were both risk factors for lost to follow-up, with a cumulative OR of 6.9 when analyzed as having attended 2 or fewer follow-up appointments (95% CI = 2.916-16.375). This contrasts with having attended only 3 appointments, in which the risk stops being statistically significant (OR = 1.138, 95% CI = 0.438-2.951).

On the multivariable model, a patient being 10 years old or older (OR = 13.466, 95% CI = 2.792-64.958) and attendance to 2 or fewer follow-up appointments (OR = 19.027, 95% CI = 4.991-72.533) continue to be a statistically significant risk factor for loss to follow-up even when controlling for living with at least 1 biological parent and involvement in sports. Figure summarizes the most significant risk and protective factors found. Table V shows the complete results of the univariate and multivariate analyses.

Discussion

Through this single-center cohort of pediatric patients with mTBI receiving follow-up management by the concussion clinic at a safety-net hospital, we identified significant protective and risk factors for loss of follow-up after a concussion. This is the first paper in the literature to look at this outcome.

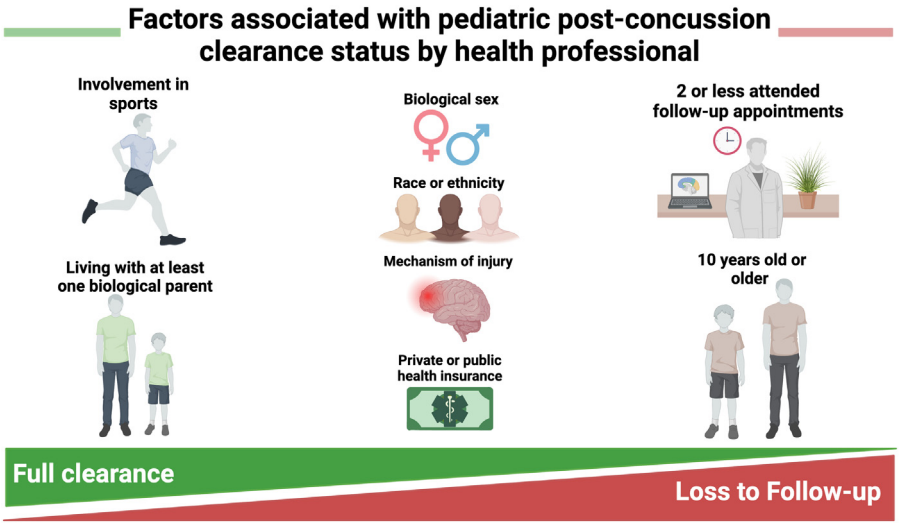

Figure. Factors associated with pediatric postconcussion clearance status by health professional. Created in BioRender. Nunez, E., et al. (2024) BioRender.com/l49u761.

Living with at least one biological parent and involvement in sports were significant protective factors. The former has never been reported in the literature. Nevertheless, studies in chronic neurological conditions in the pediatric population have reported that parents' concern and understanding of possible long-term repercussions can function as a facilitator of care.[29,43,44] Involvement in sports being a protective factor is most likely associated increased public awareness of mTBI and its sequelae, as well as regulations regarding concussions and sports. The General Law of Massachusetts, 105 CMR 201.000, states that a student diagnosed with a concussion by a medical professional or suspected of suffering one, cannot return to practice or competition of any athletic activities until written authorization by a licensed health care professional is provided.[45] This works as a positive incentive to continue follow-up visits until full clearance is obtained. Also, by state law, as a prerequisite for involvement in extracurricular athletic activities, students and their parents must complete an approved training regarding head injuries and concussions and provide the school with a certificate of completion.[45]

The most prominent risk factors for loss to follow-up were age and having attended two or fewer follow-up appointments. According to this study, age is directly proportional to risk for loss to follow-up, with older patients being at the highest risk, specifically those 10 years old or older, which is when adolescence begins.[42] The decrease in attendance to medical follow-up appointments among older children is a phenomenon that has been previously reported across several diseases and settings.[46-50] Our study is the first to describe this in pediatric concussion patients. Increased independence, fear of rejection by peers due to the potential need for accommodations, deeming appointments as unnecessary, and down-playing of symptoms to minimize disruption of established routines, are some of the possible reasons for an increased risk of loss to follow-up among older age groups.[17]

Having attended 2 or fewer follow-up appointments has not been reported in the literature before as a risk factor for loss of follow-up in concussion patients. In our study, 4-8 appointments are necessary before the patient can obtain full clearance to return to regular activities, including contact sports. The number of appointments a patient needs is completely individualized, with patients with higher symptom burden, and/or presence of risk factors for poor outcomes usually needing more close-up monitoring.[16,25] Attending 2 or fewer appointments is a significant risk factor, but after attending 3 or more visits, the risk for loss to follow-up stops being statistically significant. This novel finding provides an important view of this "golden window," on which patients and their families self-determine the degree of importance of attending follow-up appointments and reaching full clearance. This suggests that in those first 2 appointments, medical professionals should prioritize building rapport with patients and their families. The latter should emphasize open communication, a clear understanding of the management plan and objectives for future visits, as well as the importance of postconcussion care and clearance.

Mohammed et al (2023) focused on adherence to primary care visits regarding concussion follow-up. In contrast with ours, this study was set in a wide network of primary practice offices, not in a single specialty concussion clinic. They also had a broader definition for follow-up adherence which included continued follow-up until provider clearance to return to full activity, no more than 2 no-show visits, and for those referred to a specialty concussion clinic to have attended at least 1 visit. For primary care, there was a decrease in adherence in non-Hispanic Black patients and patients with public insurance. However, when focused on attending at least one visit of patients referred to a concussion specialty clinic, the study found no differences in race/ethnicity or insurance status.[35] The latter is consistent with our reported findings.

This study has several strengths, including being set in a specialty concussion clinic of a safety-net hospital, with our sample population having a similar proportion of White, Black, and Latino/Hispanic patients. We also controlled for a wide range of demographic and socioeconomic variables, as well as variables surrounding concussion events and follow-up management, giving us the ability to control for possible cofounders. As for limitations, this study is single center, which may affect to reproducibility of results in other centers. Our sample size is also modest, which limits power. Nevertheless, the novel findings of this study serve as groundwork for future multicenter retrospective and prospective studies. The study was also limited by lack of clear classification of payment structure and insurance plan at the time of the concussion, since the EMR only reflects the current plan, which may have changed since the initial injury. Also, few appointments were carried out via telemedicine, so the effects of this modality on follow-up success could not be evaluated.

Further research is needed regarding factors influencing postconcussion follow-up success or lack thereof in the pediatric population. This should include variables like _comorbidities before and after a concussion event, novel strategies to increase patient and caregiver's understanding of the importance of follow-up during the first couple of appointments, and different modalities (telemedicine, phone calls, etc.) that may enhance patients' adherence to follow-up.

Conclusion

Our study identified significant protective and risk factors for loss to follow-up. Living with at least one biological parent and involvement in sports were shown to be protective factors for loss to follow-up. Attendance to 2 or less follow-up appointments and being 10 years old or older at the time of concussion are associated with significant increase in the risk for loss to follow-up. Special attention should be placed in the "golden window" of the first 2 follow-up appointments. This window is crucial for establishing good rapport and communication with patient and family to facilitate reaching the goal of full clearance. Emphasis should be placed on patient and caretaker understanding of the health benefits of proper clearance to return to full activity after a concussion and the possible consequences of being lost to follow-up. This study did not find significant differences between biological sex, race, ethnicity, driving time to concussion clinic center, type of insurance, clinical signs in concussion event, and mechanism of injury. Prospective research is needed regarding factors influencing postconcussion follow-up success or lack thereof in the pediatric population. Following studies may need to incorporate phone follow-up for no-shows to better determine reasons and factors related to loss to follow-up. Understanding these factors will help create management plans for increasing the rate of pediatric postconcussion patients reaching full clearance. Future directions should also include prospective studies that implement strategies targeted to adolescent patients and building a strong patient-physician relationship in the first two follow-up appointments. ■

CRediT authorship contribution statement

Emilia Núñez-Peña: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ryan P. Kelly:** Writing – review & editing, Methodology, Investigation, Data curation, Conceptualization. **Santiago Campos:** Writing – review & editing, Investigation, Data curation. **Maria C. Diaz:** Writing – review & editing, Investigation, Data curation. **Pamela A. Castillo:** Writing – review & editing, Investigation, Data curation. **Shivangi Kataria:** Writing – review & editing, Methodology, Formal analysis. **Alexia M. Perez:** Writing – review & editing, Project administration. **Maria Dolores Beletanga:** Writing – review & editing, Project administration. **Alcy R. Torres:** Writing – review & editing, Supervision, Project administration, Data curation, Conceptualization.

Declaration of Competing Interest

None of the authors have conflicts of interest to disclose. No funding was secured for this study.

Submitted for publication Jun 15, 2024; last revision received Oct 14, 2024; accepted Oct 15, 2024.

Reprint requests: Alcy R. Torres, MD, Department of Pediatrics, Boston Medical Center, 801 Albany St, Boston, MA 02482. E-mail: artorres@bu.edu

References

1. James SL, Theadom A, Ellenbogen RG, Bannick MS, Montjoy-Venning W, Lucchesi LR, et al. Global, regional, and national burden of traumatic brain injury and spinal cord injury, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet Neurol 2019;18:56-87.
2. Peterson AB, Thomas KE, Zhou H. Surveillance report of traumatic brain injury-related deaths by age group, sex, and mechanism of injury—United States, 2018 and 2019. Atlanta, GA: Centers for Disease Control and Prevention; 2022.
3. Bryan MA, Rowhani-Rahbar A, Comstock RD, Rivara F. Sports-and recreation-related concussions in US youth. Pediatrics 2016;138:e20154635.
4. Centers for Disease Control and Prevention. Surveillance report of traumatic brain injury-related emergency department visits, Hospitalizations, and Deaths—United States, 2014. Centers for Disease Control and Prevention, US Department of Health and Human Services [Internet]. 2019. Accessed November 3, 2023. www.cdc.gov/TraumaticBrainInjury
5. Arbogast KB, Curry AE, Pfeiffer MR, Zonfrillo MR, Haarbauer-Krupa J, Breiding MJ, et al. Point of health care entry for youth with concussion within a large pediatric care network. JAMA Pediatr 2016;170:e160294.
6. Centers for Disease Control and Prevention. Report to Congress: the management of traumatic brain injury in children. Chicago, IL: National Center for Injury Prevention and Control; Division of Unintentional Injury Prevention; 2018. Accessed October 27, 2024. jamanetwork.com
7. Wittevrongel K, Barrett O, Couloigner I, Bertazzon S, Hagel B, Schneider KJ, et al. Longitudinal trends in incidence and health care use for pediatric concussion in Alberta, Canada. Pediatr Res 2023;93:1752-64.

8. Shahrestani S, Ballatori AM, Ton A, Chen XT, Zargarian A, Chan AK, et al. Demographic-dependent risk of developing severe novel psychiatric disorders after concussion. J Neurotrauma 2022;39:131-7.
9. Russell K, Walld R, Bolton JM, Chateau DD, Ellis MJ. Incidence of subsequent mental health disorders and social adversity following pediatric concussion: a longitudinal, population-based study. J Pediatr 2023;259:113436.
10. van Ierssel JJ, Tang K, Beauchamp M, Bresee N, Cortel-Leblanc A, Craig W, et al. Association of posttraumatic headache with symptom burden after concussion in children. JAMA Netw Open 2023;6:E231993.
11. Keller LJ, Berthiaume SM, Landry KJ, Bolno AL, Winkelmann ZK. Childhood mental health outcomes following mild traumatic brain injury: an evidence-to-practice review. Clin Pract Athl Train 2023;6:61-6.
12. Eisenberg MA, Meehan WP, Mannix R. Duration and course of postconcussive symptoms. Pediatrics 2014;133:999-1006.
13. Jain B, Das AK, Agrawal M, Babal R, Purohit DK. Implications of DTI in mild traumatic brain injury for detecting neurological recovery and predicting long-term behavioural outcome in paediatric and young population—a systematic review. Childs Nerv Syst 2021;37:2475-86.
14. Ledoux AA, Tang K, Yeates KO, Pusic MV, Boutis K, Craig WR, et al. Natural progression of symptom change and recovery from concussion in a pediatric population. JAMA Pediatr 2019;173:e183820.
15. Gornall A, Takagi M, Morawakage T, Liu X, Anderson V. Mental health after paediatric concussion: a systematic review and meta-analysis. Br J Sports Med 2021;55:1048-58.
16. Velikonja D. Standards for post-concussion care [Internet]. 2017. Accessed November 3, 2023. https://pedsconcussion.com/wp-content/uploads/2021/07/Standards-for-Post-Concussion-Care-2017-en.pdf
17. Karlin AM. Concussion in the pediatric and adolescent population: "different population, different concerns". PM R 2011;3:S369-79.
18. Anderson V, Catroppa C, Godfrey C, Rosenfeld JV. Intellectual ability 10 years after traumatic brain injury in infancy and childhood: what predicts outcome? J Neurotrauma 2012;29:143-53.
19. Davis GA, Anderson V, Babl FE, Gioia GA, Giza CC, Meehan W, et al. What is the difference in concussion management in children as compared with adults? A systematic review. Br J Sports Med 2017;51:949-57.
20. Snedden TR, Pierpoint LA, Currie DW, Comstock RD, Grubenhoff JA. Postconcussion academic support in children who attend a primary care provider follow-up visit after presenting to the emergency department. J Pediatr 2019;209:168-75.
21. Kaye AJ, Gallagher R, Callahan JM, Nance ML. Mild traumatic brain injury in the pediatric population: the role of the pediatrician in routine follow-up. J Trauma 2010;68:1396-400.
22. Choe M, Barlow KM. Pediatric traumatic brain injury and concussion. Continuum 2018;24:300-11.
23. Lumba-Brown A, Yeates KO, Sarmiento K, Breiding MJ, Haegerich TM, Gioia GA, et al. Centers for disease control and prevention guideline on the diagnosis and management of mild traumatic brain injury among children. JAMA Pediatr 2018;172:e182853.
24. Lumba-Brown A, Yeates KO, Sarmiento K, Breiding MJ, Haegerich TM, Gioia GA, et al. Centers for disease control and prevention guideline on the diagnosis and management of mild traumatic brain injury among children. JAMA Pediatr 2018;172:e182847.
25. Lumba-Brown A, Yeates KO, Sarmiento K, Breiding MJ, Haegerich TM, Gioia GA, et al. Diagnosis and management of mild traumatic brain injury in children. JAMA Pediatr 2018;172:e182847.
26. Ellis MJ, Bauman S, Cowle S, Fuselli P, Tator CH. Primary care management of concussion in Canada. Paediatr Child Health 2019;24:137-42.
27. Wittevrongel K, Barrett O, Hagel BE, Schneider KJ, Johnson DW, Yeates KO, et al. Factors associated with follow-up care after pediatric concussion: a longitudinal population-based study in Alberta, Canada. Front Pediatr 2023;10:1035909.
28. Ramsay S, Dahinten VS, Ranger M, Babul S. Follow-up visits after a concussion in the pediatric population: an integrative review. NeuroRehabilitation 2023;52:315-28.
29. Currie D, Snedden T, Pierpoint L, Comstock RD, Grubenhoff JA. Factors influencing primary care follow-up after pediatric mild traumatic brain injury. J Head Trauma Rehabil 2019;34:E11-9.
30. Lundine JP, Peng J, Chen D, Lever K, Wheeler K, Groner JI, et al. The impact of driving time on pediatric TBI follow-up visit attendance. Brain Inj 2020;34:262-8.
31. Crandall M, Rink RA, Shaheen AW, Butler B, Unger E, Zollman FS. Patterns and predictors of follow-up in patients with mild traumatic brain injury. Brain Inj 2014;28:1359-64.
32. Tarimala A, Singichetti B, Yi H, Huang L, Doerschuk R, Tiso M, et al. Initial emergency department visit and follow-up care for concussions among children with Medicaid. J Pediatr 2019;206:178-83.
33. Seabury SA, Gaudette É, Goldman DP, Markowitz AJ, Brooks J, McCrea MA, et al. Assessment of follow-up care after emergency department presentation for mild traumatic brain injury and concussion: results from the TRACK-TBI study. JAMA Netw Open 2018;1:e180210.
34. Zuckerman SL, Brett BL, Jeckell AS, Yengo-Kahn AM, Solomon GS. Prognostic factors in pediatric sport-related concussion. Curr Neurol Neurosci Rep 2018;18:104.
35. Mohammed FN, Master CL, Arbogast KB, McDonald CC, Sharma S, Kang B, et al. Disparities in adherence to concussion clinical care recommendations in a pediatric population. J Head Trauma Rehabil 2023;38:147-55.
36. Sutton JP, Washington RE, Fingar KR, Elixhauser A. Characteristics of Safety-Net Hospitals, 2014. In: HCUP statistical Brief #213. Rockville, MD: Agency for Healthcare Research and Quality; 2006.
37. Carroll LJ, Cassidy JD, Holm L, Kraus J, Coronado VG. Methodological issues and research recommendations for mild traumatic brain injury: the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. J Rehabil Med 2004: 113-125.
38. Silverberg ND, Iverson GL, Cogan A, Dams-O-Connor K, Delmonico R, Graf MJP, et al. The American Congress of Rehabilitation Medicine Diagnostic criteria for mild traumatic brain injury. Arch Phys Med Rehabil 2023;104:1343-55.
39. Kuppermann N, Holmes JF, Dayan PS, Hoyle JD, Atabaki SM, Holubkov R, et al. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. Lancet 2009;374:1160-70.
40. Rice SG, Small EW, McCambridge TM, Benjamin H, Bernhardt DT, Brenner JS, et al. Medical conditions affecting sports participation. Pediatrics 2008;121:841-8.
41. Cohen R, Baluch B, Duffy LJ. Defining extreme sport: conceptions and misconceptions. Front Psychol 2018;9:1974.
42. Patton GC, Sawyer SM, Santelli JS, Ross DA, Afifi R, Allen NB, et al. Our future: a Lancet commission on adolescent health and wellbeing. Lancet 2016;387:2423-78.
43. Keenan RP, Lovanio K, Lapidus G, Chenard D, Smith S. Improved concussion discharge instructions in a pediatric emergency department. Adv Emerg Nurs J 2020;42:63-70.
44. Hwang V, Trickey AW, Lormel C, Bradford AN, Griffen MM, Lawrence CP, et al. Are pediatric concussion patients compliant with discharge instructions? J Trauma Acute Care Surg 2014;77:117-22.
45. Massachusetts Department of Public Health. 105 CMR 201.00: head injuries and concussions in extracurricular activities. Massachusetts General Law. Accessed November 20, 2023. https://www.mass.gov/regula

tions/105-CMR-20100-head-injuries-and-concussions-in-extracurricular-activities#:~:text=105%20CMR%20201.000%20provides%20standardized,in%20order%20to%20protect%20their
46. Spaw AJ, Lundine JP, Johnson SA, Peng J, Wheeler KK, Shi J, et al. Follow-up care adherence after hospital discharge in children with traumatic brain injury. J Head Trauma Rehabil 2018;33:E1-10.
47. Irwin CE, Millstein SG, Ellen JM. Appointment-keeping behavior in adolescents: factors associated with follow-up appointment-keeping. Pediatrics 1993;92:20-3.
48. Chariatte V, Berchtold A, Akré C, Michaud PA, Suris JC. Missed appointments in an outpatient clinic for adolescents, an approach to predict the risk of missing. J Adolesc Health 2008;43:38-45.
49. Atger-Lallier L, Guilmin-Crepon S, Boizeau P, Zenaty D, Simon D, Paulsen A, et al. Factors affecting loss to follow-up in children and adolescents with chronic endocrine conditions. Horm Res Paediatr 2019;92:254-61.
50. Kranzer K, Bradley J, Musaazi J, Nyathi M, Gunguwo H, Ndebele W, et al. Loss to follow-up among children and adolescents growing up with HIV infection: age really matters. J Int AIDS Soc 2017;20:21737.