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The Course of Concussion Recovery in Children 6–12 Years of Age: Experience from an Interdisciplinary Rehabilitation Clinic

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Abstract

Background—Current concussion evidence is largely derived from teenagers and adults. Concussion in younger children occurs within the context of neuro-maturation, with differing age-based pathophysiological responses to injury. Therefore our current understanding of concussion in older children and adults is unlikely to directly apply to younger children.

Objective—To describe patient variables, clinical course, and factors associated with time to discharge from concussion care in children 6 – 12 years of age with concussion treated in an interdisciplinary rehabilitation-based concussion clinic.

Design—Retrospective chart review.

Setting—Interdisciplinary concussion clinic at an academically-affiliated rehabilitation center.

Patients—Children aged 6 – 12 years (n= 105; mean 10.8 years of age, 70% male) seen within 60 days of concussive injury.

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Main Outcome Measurements—Descriptive statistics explored demographic, injury, and clinical features. The primary outcome measure, time to discharge from concussion care, was estimated using survival-analysis methods based on the date of discharge from the clinic. Multivariate models were used to examine factors associated with longer time to discharge.

Results—Median time to discharge was 34 days post-injury (range 5–192 days); 75% of children were discharged within 60 days of injury. A minority reported persisting symptoms at discharge. Younger age and increased symptom burden at initial evaluation predicted longer time to discharge.

Conclusions—While children 6–12 years old treated in a specialty concussion clinic show variability in time to discharge from concussion care, most were discharged within 2 months following injury. Risk factors for prolonged recovery, such as younger age and higher symptom burden at initial visit, can be used when counseling families and planning interventions. There may be varying contributions, including psychosocial stressors, to ongoing symptoms in children who experience persisting symptoms after other concussion-related concerns have resolved. Future work focused on the subset of children who report persisting symptoms will be useful for developing an evidence base related to their care.

Keywords

concussion; mild traumatic brain injury; brain concussion; post-concussion symptoms; pediatric; retrospective study

Introduction

Rates of mild traumatic brain injury (mTBI or concussion) in youth are difficult to document due to variability in whether and where care is sought. In a report of one geographic area, visits to primary care providers for youth mTBI have increased more than 4-fold in the past decade, and over the same period of time, visits to specialists have increased more than 9-fold.¹ Medical visits for youth concussion are directed toward management of post-concussive symptoms and determining when a child has clinically recovered and can return to all activities; the standard for discharge from concussion care in a child with a typical clinical course is resolution of both injury-related symptoms and any deficits in motor and cognitive function.²

The anticipated timeline for clinical recovery after concussion and the factors that impact this timeline are of primary importance to youth, their caregivers, and medical providers. Initial evidence regarding the timeframe for recovery from youth concussion came largely from high-school and college athletes with sports-related injuries. In this population, historically most youth were reported to be medically cleared to return to play within 1 month post-injury.^{3,4} As many athletes may be strongly motivated to return to play and sports-related injuries account for only a portion of concussions in younger children, data from high-school and college athletes may not best represent the recovery timeline of young children with concussion, many of whom do not participate in organized sports.

For youth in whom recovery extends beyond the first weeks after injury, care is often sought in specialty clinics.^{5,6} Recently, data from specialty clinics are coalescing to describe a

population of youth who are slower to recover, though variability still exists among reports. Kriz et al. reported on 13–18 year old hockey players who were seen in one of 3 hospital-affiliated sports medicine clinics up to 6 months post-injury (with the majority seen within 3 weeks post-injury); mean time to resolution of symptoms was 45 days.⁶ Heyer et al reported on a large population of youth aged 10–19 years (mean age 14 years) who were initially seen in a sports medicine clinic within 30 days of injury; in this group, median time to resolution of symptoms was 18 days.⁷ Corwin et al. reported on youth aged 7–18 years who were initially seen in a sports medicine clinic a median of 12 days but up to 2 years post-injury; they observed a median of 64 days until symptom-free and 76 days until fully cleared.⁵

Age has emerged as one possible modifier of time to recovery after concussion in youth with prolonged symptoms. Recently, Corwin et al. found a longer time to symptom resolution in their youth aged 7–12 years compared to youth aged 13–18, though this difference did not reach statistical significance, and no difference was observed in time to full clearance.⁵ Kriz et al. found that earlier pubertal status was associated with longer time to recovery in the male teenaged hockey players that they studied.⁶ Heyer et al. did not find that age was associated with protracted recovery, though the mean age of the cohort was 14 years, and it was not stated how many children were aged 10–12 years.⁷

Younger children may experience a more protracted recovery period following concussion compared to older youth for multiple reasons. In more severe TBI, younger children are known to have worse cognitive, motor, and academic outcomes than older children,^{8–10} potentially due to contributions from the stage of brain development at the time of injury¹¹ as well as due to age-dependent physiological responses to injury.¹² Furthermore, younger children incur a higher rate of concussions from non-sports mechanisms,^{13,14} and non-sports related injuries have been associated with higher symptom reports at presentation^{15,16} as well as longer time to recovery.¹⁶

Work from other specialty clinic populations has yielded some variability in additional factors associated with longer time to recovery in generally older youth (teenagers). Higher symptom score at presentation to the specialty clinic has been associated with prolonged recovery.^{6,7} Female gender has been directly associated with prolonged recovery⁷ as well as with higher symptom ratings.¹⁵ Corwin et al. found that pre-injury history of prior concussion, depression, or anxiety and the presence of dizziness and symptom provocation with oculomotor exam were associated with longer time to recovery,⁵ while Heyer et al. found that prior headaches but not prior concussion was associated with protracted recovery.⁷ Heyer et al. also found injury severity, specifically presence of loss of consciousness (LOC) and post-traumatic amnesia, to be associated with protracted recovery only when also accounting for symptom report.⁷ Similarly, Corwin et al. reported that LOC was associated with longer time to recovery although the association did not reach statistical significance.⁵ Differences among these studies may have been related to differences in the studied populations, including variability in age, type of sports involvement, and time from injury to first visit in the specialty clinic.

In a minority of youth with concussion, post-concussive symptoms are reported to persist beyond the initial months post-injury.^{5,17,18} Given that post-concussive symptoms overlap

with symptoms reported by youth without concussion but with other diagnoses (e.g. migraines, mental health disorders, attention-deficit hyperactivity disorder and learning disabilities),¹⁹ identifying when children are recovered from concussion can be challenging. This has led to the recommendation that this population be managed by clinicians whose skill sets include evaluation of overlapping syndromes and underlying contributing factors.²⁰ Recent literature has highlighted the importance of behavioral health services,²¹ and particularly cognitive restructuring,²² for preventing and addressing persisting symptoms after childhood concussion.

Given the dearth of information specific to younger children with concussion, the objectives of this study were to describe a cohort of children 6 – 12 years of age at presentation and discharge from an interdisciplinary concussion clinic within a tertiary referral rehabilitation institute, to examine the time to discharge from concussion care in this population, and to evaluate the relationship of child, family, and injury-related variables on the time to discharge. Based on clinical experience, our primary hypothesis was that young children with concussion would experience clinical recovery over several weeks to months, and, secondarily, that higher symptom ratings at presentation to clinic and pertinent child and family history diagnoses (such as migraine, ADHD, learning and mood disorders) would be associated with a longer time until discharge.

Patients and Methods

The local Institutional Review Board granted approval for retrospective review of medical records and creation of a research database.

Study Design and Population

Records were reviewed for children aged 6 – 12 years seen in an interdisciplinary concussion clinic at an academically-affiliated rehabilitation institute between May 2010 and May 2013. Records reviewed included all provider documentation for each visit, written information provided to the family [e.g. completed Acute Concussion Evaluation (ACE) Care Plan²³], and contact notes documenting communication between providers and family outside of clinic visits. We chose to include only children whose initial evaluation in this specialty clinic occurred within 60 days post-injury in order to capture the patient population most frequently cared for in this setting. In addition, completion of care within the clinic had to have occurred by the end of the study period. Concussion was defined as direct impact to the head or body with transmitted impulsive force to the head, with associated alteration of mental status and/or one or more concussive symptoms identified within 24 hours of injury, as reported by the child and/or parent. Children with documented Glasgow Coma Scale score <13 in an emergency room, loss of consciousness (LOC) > 30 minutes, or post-traumatic amnesia (PTA) >24 hours were excluded. Children with intracranial imaging abnormalities were included if inclusion criteria were otherwise met. The final cohort included 105 children. Seven children returned for treatment of a subsequent injury within the study period; data were only included from the initial episode of care. Eighteen additional children did not meet inclusion criteria (13 were > 60 days from injury at the

initial clinic visit, 2 met criteria for moderate TBI, and 3 did not meet criteria for having sustained a TBI of any severity).

Measures

Neurorehabilitation Concussion Clinic Description—A typical initial visit to this clinic includes child, injury, and family history, comprehensive symptom report based on the Acute Concussion Evaluation (ACE),²³ administration of an age-appropriate neuropsychological screening battery, and physical examination including balance testing. Data from all sources are reviewed by providers (a physician and a neuropsychologist) and used to formulate the clinical assessment, recommendations, and referrals. While performance on individual examination measures is beyond the scope of this paper, their results contributed to the providers' determination of readiness for discharge from concussion care. Children are typically followed in clinic every 2–3 weeks until they are considered to be recovered from concussion and then are discharged from clinic. In our clinic, if children report persistent symptoms which, based on interdisciplinary evaluation, are no longer thought to be resulting from an active concussive injury, youth are discharged from the concussion clinic with referrals for continued care in other settings, such as headache clinic or cognitive-behavioral therapy.

Patient Variables

Number of prior concussions—Caregiver provided report of the number of concussions experienced by the child prior to the current injury; reported prior events were considered consistent with concussion if a medical provider had diagnosed concussion or if the caregiver reported clear post-concussive symptoms after a distinct head injury.

Child's past medical history (PMH)—PMH was documented based on caregiver report of a formal diagnosis established by a healthcare provider prior to the presenting concussion. As the younger age of our cohort may have limited the number of formal diagnoses, parental concern for a problem without formal diagnosis was also recorded. Past medical diagnoses of interest were Attention Deficit / Hyperactivity Disorder (ADHD), Learning Disability, Anxiety Disorder, Mood Disorder, Migraine / Headaches, and Sleep Difficulty. As a summary measure, the documentation of any of these medical conditions was counted as a positive PMH.

Family history (FH)—FH was coded for the report of formal diagnosis, and separately for parental concern for a problem without formal diagnosis, of the same medical conditions as specified for PMH if occurring in a parent, grandparent, or sibling of the patient. As a composite measure, documentation of any of these medical conditions was counted as a positive FH.

Concussion-Related Measures

Mechanism of injury—An injury was considered a sports-related concussion when it occurred during active participation in an organized athletic event (team or individual sport practice or competition) versus “non-sports-related” concussion, which included any other mechanism of injury. The specific mechanism was recorded.

Loss of consciousness (LOC)—The presence of LOC was recorded based on report of observed LOC at the time of injury. LOC was considered absent if documentation stated “unknown” or LOC was not reported.

Post-traumatic amnesia (PTA)—The presence of PTA was determined from report of memory loss and confusion surrounding and/or shortly after the injury. As presence of PTA is typically closely evaluated in clinic, lack of documentation was considered absence of PTA.

Acute Emergency Department evaluation—Caregiver report of seeking medical care at an Emergency Department or Urgent Care center for concussion-related concerns within 24 hours of injury was documented.

Other clinical concussion care—Caregiver report of evaluation for the current injury by another provider, such as a pediatrician, > 24 hours after injury and prior to the initial evaluation in concussion clinic was also documented.

Clinical Course Measures

Time from injury to initial evaluation (TTE)—This was calculated as the number of days from injury to initial evaluation in concussion clinic.

Number of clinical visits—This was the number of visits to concussion clinic for management of the presenting concussive injury.

Symptoms—Ongoing post-concussive symptoms, based on the ACE, were recorded from clinical documentation of providers at each visit. Symptom variables of interest included total number of symptoms reported (maximum possible 22), total symptoms in each domain (physical, cognitive, emotional, and/or sleep), and the number of symptom domains in which ongoing symptoms were reported. As only a minority of children presented with ongoing symptoms in 3 domains, children presenting with symptoms in 3–4 domains were merged for statistical analyses.

The primary outcome measure, time to discharge from concussion care (TTD), was based on documented discharge from concussion clinic (yes/no at each clinic visit) and reflects the expert opinion of the interdisciplinary team regarding whether or not the child required ongoing clinic-based assessment and care for concussion. As some children experienced complete resolution of symptoms prior to their scheduled clinic visit and some experienced symptom resolution shortly thereafter, TTD was chosen as the best surrogate for time to clinical recovery. TTD was calculated as the number of days between injury and clinic discharge. Children were not considered to be discharged from concussion care if they did not return for planned follow-up or were referred to another provider for a follow-up concussion visit (e.g. in some cases a child was referred to the pediatrician for follow-up if the child lived at a great distance from the specialty clinic, had minimal care needs, and readiness for final discharge from concussion care was anticipated to occur in the coming weeks and be straightforward to determine). Report of persisting symptoms at discharge from clinic was noted.

Persistent Symptoms at Discharge—Children were considered to have persisting symptoms at the time of clinical clearance if they reported ongoing presence of a symptom that began in association with injury or persistent worsening of a symptom which had been present at a lesser frequency or intensity prior to injury.

Statistical Analysis

All analyses were performed using STATA13.²⁴ Descriptive statistics examined patient variables (age, gender, past medical history, family history), concussion-related measures (mechanism of injury, LOC, PTA, prior concussion care, neuroimaging abnormalities, total symptoms and symptom domains at initial evaluation), and clinical course measures (TTE, TTD, persisting symptoms).

Kaplan-Meier estimator was used to describe TTD. Children who were not discharged from concussion clinic (those that did not return for planned follow-up or were referred to another provider for continued concussion management) were censored at the time of their last concussion clinic visit, such that these children were included in the Kaplan-Meier estimation as having not attained discharge through the number of days post-injury of their last visit to our clinic and then are not included in the Kaplan-Meier curve after that point. Log-rank test was used to compare the TTD by categories of patient history variables [including positive PMH, positive FH, and the two most common past medical/family diagnoses (ADHD and headache)], concussion-related measures, and symptom variables.

Logistic regression was used to evaluate the relationship between PMH and FH variables and persisting symptoms at clinic discharge. PMH and FH variables were analyzed including as positive only those with a formal diagnosis and then repeated including as positive those with formal diagnosis plus parental concern for the problem. As relationship of PMH and FH variables and TTD did not change based on inclusion or exclusion of parental concern, all data presented reflect formally diagnosed PMH and FH data.

Bivariate Cox proportional regression models were fitted to estimate hazard ratios of discharge and 95% confidence intervals for patient, concussion-related, and symptom variables. As the outcome measure is a positive event (discharge from care), in these analyses, a Hazard Ratio < 1 reflects reduced likelihood of discharge at any given time point. Various multivariate models were compared using partial log-likelihood and Akaike information criterion to define the set of variables in the most parsimonious model; as it is known a priori that TTE affects the primary clinical outcome, TTD, all candidate models included TTE. In light of prior work demonstrating worse outcomes after TBI in children who are younger vs older than 6 years⁸ as well as in children 6–12 years vs older,²⁵ for multivariate analyses, we chose to divide the current cohort by age at approximately the middle of the age range (6 through 8 years versus 9 through 12 years). The number of children younger than 9 years was limited (n=18) and did not lend itself to further division by gender; for the older group, given the prior reports of the effect of gender on recovery,^{7,15} girls and boys were examined separately.

Results

Sample Demographics

Table 1 presents past medical and family history, concussion-related measures, and clinical symptoms at initial evaluation. The majority of children were male and 9 years of age. Sports-related concussion accounted for 52% of all injuries; football was the most common cause of sports-related injuries (n = 20). Fall, such as from a bicycle or playground equipment, was the most common cause of non-sports-related injuries (n = 31).

Clinical Course

Median TTE was 15 days after injury (range: 2–57 days). Children presented to clinic reporting an average of 2 positive symptom domains; physical symptoms were most common. Table 2 summarizes the clinical course by number of clinic visits; on average, children were seen in concussion clinic for 2 visits. Figure 1 depicts TTD (range 5–192 days). Half of the children were discharged by 34 days post-injury, and 75% were discharged within 60 days post-injury. Ten children were not formally discharged: 3 did not return for scheduled follow-up, and 7 were referred to another provider for continued concussion management. Data from these children were censored (not included) after the last visit to our clinic, which was the first (n=7) or second clinic visit (n=3).

Relationship between symptoms and TTD—Median TTD for children presenting with any physical symptom at first visit was 38 days compared to 12 days for those without physical symptoms ($p < .001$, see Figure 2A), and median TTD for those with any cognitive symptom at the first visit was 43 days versus 27 days for those without cognitive symptoms ($p = .005$, see Figure 2B). Similar patterns were seen in children with and without emotional or sleep symptoms at the first visit ($p = .03$ and $p < .001$ respectively). Median TTD for children reporting no symptoms at initial evaluation was 11 days, with almost all children who reported resolution of symptoms prior to the initial clinic visit being discharged at the first visit. Median TTD for children with symptoms in 1, 2, or 3–4 symptom domains was 39 days, 34 days, and 41 days respectively ($p < .001$, see Figure 2C).

Seventeen patients had at least one persisting symptom at discharge. Six children newly developed chronic daily headache after injury, one with associated tinnitus. Three children with pre-injury headaches described more frequent headaches that persisted 2 months post-injury but that did not interfere with the child's activities and/or existed in the setting of clear contributing lifestyle factors. One child had only persisting photophobia. The median time to discharge in these 10 patients with 1–2 persisting physical symptoms was 60 days (range 20–192 days). Seven additional children reported multiple persisting symptoms (mean=4 symptoms) across symptom domains at discharge which were assessed by the clinic providers to be related to co-morbid factors, most commonly psychosocial stressors. Among these 7 children, median time to discharge was 38 days (range 30–182). Only positive family history of headache was associated with likelihood of having persisting symptoms at clinic discharge (Odds ratio 3.6 [95% CI 1.2 – 10.5], $p < .05$).

Variables associated with TTD—Table 3 presents the Bivariate Cox regression models evaluating the relationships between TTD and patient, concussion-related, and clinical variables. Higher number of symptoms per domain and greater number of domains with symptoms at initial evaluation were associated with longer TTD ($p < .05$ for all variables).

Table 4 presents the most parsimonious multivariate model of variables associated with TTD. After controlling for age, gender, and TTE, for every additional physical symptom at initial evaluation, there was a 30% reduction in likelihood of discharge (95% CI: between 19% and 40% reduction) and for every additional symptom domain, a child was 23% less likely to be discharged (95% CI: between 6% and 37% reduction in likelihood of discharge). After adjustment for TTE, number of physical symptoms and number of symptom domains reported at the initial evaluation, children <9 years of age were less likely to be discharged at any given time point compared to children ≥9 years of age (p -value = .03 for boys ≥9 years of age vs. all children <9 and p -value = .01 for girls ≥9 years of age vs. all children <9).

Discussion

This is the first clinical description of a cohort of 6–12 year old children diagnosed with concussion and evaluated in an interdisciplinary rehabilitation concussion clinic. In this sample, about half of the children had sports-related concussions. Nearly half of the patients were discharged based on the initial interdisciplinary evaluation; overall median time to discharge was 34 days post-injury. Younger age and greater number of physical symptoms and greater number of positive symptom domains at the initial clinic visit were most related to longer time to discharge, whereas a child's past medical history (including prior concussions), family history, and injury severity factors were not related to time to discharge.

In addition to the younger age of this cohort, with 70% boys, our population was slightly more biased toward male children compared to the populations reported across sports medicine clinics (58%⁷ and 63%⁵) but was similar to the gender mix in a population of hockey players.⁶ As expected, the current cohort had a higher percentage of non-sports-related injuries (48%) compared to a sports medicine clinic sample (23%).⁵ Our population also included a larger percentage of children with no prior concussions (79%) compared to rates reported in prior work that included older youth [69%⁷ and 64%⁵]; contributions to this lower rate of prior injuries likely included the younger age of the current cohort and may have also been related to the rehabilitation setting/higher rate of non-sports-related injuries. Though 42% of children in our cohort had a pertinent positive past medical history, the frequency of these diagnoses is largely consistent with prior reports of youth presenting with concussion to pediatric emergency departmentss.^{26,27} This suggests that our specialty clinic sample was not more medically complex than emergency department cohorts. Complete family history in children with concussion has not been previously reported.

The median time from injury to discharge in the current specialty clinic cohort (34 days) falls within the range previously reported for older youth seen in specialty sports medicine clinics, which ranged from 18⁷ to 76 days.⁵ Methodological differences make direct comparisons between cohorts challenging. In particular, time to discharge is influenced by

time to initial evaluation, and thus our inclusion of only children who presented for initial evaluation in our clinic by 60 days post-injury likely contributes to the shorter time to clearance compared to the work by Corwin et al.⁵ It is possible that the interdisciplinary nature of our rehabilitation-based clinic, which provided for a consistent message to be delivered to families from specialists with expertise in physical and cognitive/emotional symptoms, may have influenced the recovery trajectory.

A minority of our sample (16%) continued to report symptoms at the time that the providers felt, based on interdisciplinary evaluation, that discharge from concussion care, including the provision of clearance to continue gradual return to all activities was appropriate; this rate is similar to that previously reported.¹⁷ As would be expected, the median time to discharge was longer in this subgroup than for the whole cohort, and thus the inclusion of these youth had an influence of prolonging the overall median time to discharge for the entire sample. This longer period of care in the concussion setting for youth with persisting symptoms reflects the additional time typically needed to assess rate of change in symptoms, evaluate response to interventions, and to establish rapport with the child and parent in order for the providers to feel most confident in their assessment and to effectively transition the family to another care setting.

Qualitatively, children with persistent symptoms at the time of discharge were found to fall into two groups. Ten children (10% of the total sample) reported one or two physical symptoms (typically headache with or without an associated symptom) and no cognitive/emotional/sleep symptoms. Seven children (7% of the total sample) reported multiple symptoms across domains and had prominent psychosocial stressors; this is consistent with prior reports of non-injury-related family and child factors predicting report of persisting symptoms.²⁸ Consistent with a prior report, a family history of migraine/headaches was related to the development of persisting symptom(s), although the strength of this association is not certain in our sample given the wide confidence interval. It remains unclear if this relationship results from biological susceptibility, psychosocial factors, and/or provider bias. Longitudinal cohort studies are needed to better understand factors related to persisting symptoms as well as the long term outcomes in this subgroup.

The relationship between greater symptom burden and longer TTD has been reported from prior specialty clinic populations^{5,7} and is expected as clinical discharge is partially based on symptom resolution. In particular, symptom burden at presentation to specialty clinic has been reported to be more informative than symptom burden on the day of injury.⁷ Our finding of a strong association between the number of symptom domains endorsed at initial specialty evaluation and time to discharge is consistent with the findings from Heyer et al. of the predictive nature of symptom clusters crossing multiple domains for prolonged recovery.⁷ This suggests that the number of symptom domains endorsed by 1–2 weeks post-injury may be a useful clinical marker for children who are at risk for prolonged recovery and may benefit from interdisciplinary rehabilitative management.

After controlling for symptom burden and TTE, we found that the older children in our cohort (9–12 years) were more likely to be discharged from concussion care earlier post-injury compared to younger children (6–8 years); while this may be related to slower

recovery in younger school-aged children, it is also possible that parents and even experienced providers find it more challenging to assess return to typical function in younger children. Interestingly, in recent studies of symptom report alone (without associated clinical evaluation) in broader pediatric age groups (2–12 years²⁷ and 5–18 years²⁹), younger children were reported to have faster recovery from typical concussion symptoms. The discrepancy with our finding may reflect the concern that typical post-concussive symptom inventories are not as reliable in younger children^{30,31} and/or that in a clinical setting caregivers and providers identify other longer-lived changes after injury which impact clinical decision-making. Unlike recent reports of older youth (mean age 14 years) with sports-related concussion,^{7,20} female gender was not associated with longer time to discharge in our sample of younger children with concussion of any etiology. Despite findings in previously reported cohorts, child and parent history variables^{28,32,33} and history of prior concussions^{34,35} were not related to TTD within our sample, although report of prior concussions was very low in our sample. These associations may differ based on the child's age at injury and/or differences in management approach.

Our findings that LOC and PTA, commonly considered markers of injury severity, are not associated with TTD are consistent with several other recent studies.^{18,28,36,37} However, in a large population of youth 10–19 years of age with sports related concussion presenting within 30 days of injury, Heyer et al. did identify a relationship of LOC and PTA with longer recovery, although female gender and symptoms at presentation were stronger predictors of recovery time.⁷ It is possible that these injury severity variables have a stronger predictive nature when the population examined is restricted to those presenting within the first month post-injury; this is consistent with injury-related factors being strongly related to outcome earlier after injury.²⁸

Limitations/Future Directions

As a retrospective chart review, clinical information was based upon documentation from multiple providers with variability in level of detail. As a specialty clinic, the population is biased toward children who do not rapidly recover within the initial days post-injury though the effects of this selection bias were minimized by excluding children whose injury had occurred more than 60 days prior to clinic presentation. Because these data are based on time to clinical evaluation, and many children were discharged at the first visit to our clinic, for some children the time to discharge would have been earlier had they been seen in clinic earlier. While the time to discharge from care in our population is within the range of clinical recovery as reported by other specialty clinics, these findings are not able to be generalized to all children with concussion, and it is important to remember that many children appear to recover quickly from concussion and do not require care in a specialty setting. As there are currently no objective measures of concussion, discharge from concussion care is based on clinical evaluation, though other work suggests that changes in brain function may persist even when current clinical measures normalize.³⁸ Furthermore, while methodological differences make it difficult to directly compare samples across studies, the current data provide the first description of the recovery trajectory and associated factors in children aged 6–12 years with concussion. In future work, the precise

timeframe of clinical clearance will be most clearly evaluated in prospective longitudinal studies including youth of all ages.

Conclusion

This cohort of children aged 6–12 years with concussion who were referred for care in a specialty rehabilitation-based clinic showed a wide range in time to clinical recovery, though most were discharged from care within 2 months. Younger age, greater number of physical symptoms and greater number of positive symptom domains at initial clinic visit were most related to likelihood of clinical discharge; therefore, these factors may serve as the best clinical indicators for anticipating prolonged symptom duration and may warrant earlier interdisciplinary care. Future studies examining broader cohorts of children with clinical evaluations at regular intervals post-injury may assist with elucidating how clinical concussion recovery varies across age groups and clarify factors that most influence outcome.

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Abbreviations

ACE	acute concussion evaluation
ADHD	attention deficit/ hyperactivity disorder
FH	family medical history
LOC	loss of consciousness
PMH	past medical history
PTA	post-traumatic amnesia
TTE	time from injury to initial evaluation
TTD	time to discharge

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Figure 1.

Kaplan-Meier curve of proportion of patients not discharged from concussion clinic from the time of injury; shaded area represents 95% confidence interval for the curve.

Figure 2.

Kaplan-Meier curve of proportion of patients not discharged from concussion clinic from the time of injury by A. presence of physical symptoms, B. presence of cognitive symptoms, and C. total number of present symptom domains. In all cases symptoms represent those present at the initial concussion clinic evaluation.

Table 1

Sample Demographics and Concussion Characteristics (N=105)

	Variable	N (%)
	Age (years) Mean (SD)	10.8 (1.8)
Patient History	Male	74 (70%)
	1 prior concussion	22 (21%)
	Positive past medical history	44 (42%)
	Attention deficit / hyperactivity disorder	14 (13%)
	Headaches / migraines	21 (20%)
	Anxiety	9 (9%)
	Mood disorder	4 (4%)
	Language / learning disorder	10 (10%)
	Sleep difficulties	4 (4%)
Family History	Positive family history	61 (58%)
	Attention deficit / hyperactivity disorder	23 (22%)
	Headaches / migraines	30 (29%)
	Anxiety	10 (10%)
	Mood disorder	14 (13%)
	Language / learning disorder	12 (11%)
	Sleep difficulties	8 (8%)
Concussion Related Measures	Sports related concussion	55 (52%)
	Loss of consciousness	15 (14%)
	Post traumatic amnesia	29 (28%)
	Acute ED evaluation	70 (67%)
	Abnormal Head CT	3 (3%)
	Concussion care prior to initial evaluation	100 (95%)
Symptoms Present at Initial Clinic Evaluation	Physical	74 (71%) [2.2 (0–8)] *
	Cognitive	42 (40%) [0.6 (0–4)] *
	Sleep	47 (45%) [0.6 (0–4)] *
	Emotional	49 (47%) [0.6 (0–4)] *
	No Symptoms	26 (25%)
	1–2 positive Symptom Domains	32 (31%)
	3–4 positive Symptom Domains	47 (45%)

CT = computed tomography;

* [Mean number (range)] of symptoms reported

Table 2

Clinical Characteristics by Number of Concussion Clinic Visits

Number of Total Visits	N (%)	Days from Injury to Initial Evaluation Median (25 th – 75 th percentile)	Days from Injury to Discharge Median (25 th – 75 th percentile)	Total Number of Symptoms at Initial Evaluation Median (range)
1	47 (45%)	14 (10–29)	15 (10 –34)	0 (0–16)
2	41 (39%)	16 (12–21)	37 (27 –55)	5 (1–14)
3	14 (13%)	15 (9–26)	66 (61 –77)	6 (2–14)
4	1 (1%)	17	-	6
5	2 (2%)	21.5 (16–27)	114 (114 –182)	9.5 (8–11)

Table 3

Bivariate Cox Regression Model of Time to Discharge

Variable	Hazard ratio [*] (95% CI)	p value
Patient Variables		
Age (for every additional 1 year of age)	.95 (.86, 1.06)	.39
Gender		
Male	1 (reference)	.45
Female	.84 (.54, 1.31)	
Prior Concussions		
No	1 (reference)	.70
Yes	.90 (.54, 1.5)	
Past Medical History		
No	1 (reference)	.61
Yes	1.11 (.74, 1.67)	
Family History		
No	1 (reference)	.55
Yes	.88 (.58, 1.33)	
Injury-related Variables		
Mechanism of Injury		
Non-sport	1 (reference)	.35
Sport	.82 (.54, 1.24)	
Loss of Consciousness		
No	1 (reference)	.54
Yes	1.2 (.68, 2.12)	
Post-traumatic Amnesia		
No	1 (reference)	.16
Yes	1.39 (.88, 2.19)	
Clinical Variables		
# of Physical Symptoms at initial evaluation (for each additional symptom) (10 total)	.73 (.65, .83)	<.001
# of Cognitive Symptoms at initial evaluation (for each additional symptom) (4 total)	.74 (.58, .94)	.01
# of Mood Symptoms at initial evaluation (for each additional symptom) (4 total)	.73 (.55, .97)	.03
# of Sleep Symptoms at initial evaluation (for each additional symptom) (4 total)	.61 (.44, .84)	.003

Variable	Hazard ratio * (95% CI)	p value
# of Symptom Domains at initial evaluation (for each additional domain) (4 total)	.70 (.60, .82)	<.001

* Hazard ratio <1 indicates a lower chance of discharge from specialty concussion care at any given number of days post-injury

Table 4

Most Parsimonious Multivariate Cox Regression Model of Time to Discharge

Variable	Hazard Ratio (95% CI) ^a	p-value
Age (years)/Gender Groups		
6–8 years, Boys and Girls (n = 18)	1 (reference)	
9–12 years, Boys (n = 62)	1.95 (1.05, 3.62)	.03
9–12 years, Girls (n = 25)	2.63 (1.27, 5.46)	.01
Time to initial evaluation (TTE) (for every additional day)	0.93 (0.91, 0.95)	< .001
Number of physical symptoms at initial evaluation (for each additional symptom)	0.70 (0.60, 0.81)	< .001
Total number of symptom domains at initial evaluation (for each additional domain)	0.77 (0.63, 0.94)	.01

^aHazard ratio <1 indicates a lower chance of discharge from specialty concussion care at any given number of days post-injury