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The Relation between Parental and Family Functioning and Post-concussive Symptoms after Pediatric Mild Traumatic Brain Injury

by

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Abstract

Mild traumatic brain injuries (TBI) are commonly sustained by children and adolescents. An extensive literature documents the reciprocal relationship between family functioning and outcomes of childhood moderate and severe TBI, however, the influence of parental and family functioning on children's post-concussive symptoms (PCS) after mild TBI is not well understood. The goal of this dissertation was to examine the influence of parental and family functioning on PCS after mild TBI. Study 1 consists of a scoping review that examined the existing research on the relationship between parental and family functioning and pediatric mild TBI to determine relevant parental and family factors, summarize findings, and identify areas for further research. Study 2 consists of an original research study that aimed to identify distinct trajectories of PCS after mild TBI in 8- to 16-year-old children and to examine their association with parental and family functioning, as compared to children with orthopedic injuries (OI). Study 1 identified 15 articles that address three questions: (1) Does mild TBI result in more parental distress or poorer family functioning than other injuries?; (2) Does pre-injury or acute parental distress and family functioning predict PCS after mild TBI?; and (3) Does acute PCS predict later parental distress and family functioning? Overall, findings were mixed, although the available evidence suggests that parent and family functioning may have an important, perhaps bidirectional, association with PCS after pediatric mild TBI. Study 2 employed group-based multi-trajectory modeling to classify children into distinct trajectories of child- and parent-reported cognitive and somatic PCS across the first 6 months post-injury and to examine parental and family functioning as predictors of those trajectories. Several parental and family factors were identified as significant predictors of trajectory membership after mild TBI, including parental adjustment, protectiveness, and social support. Study 2 demonstrates that better parental functioning tends to be associated with a more rapid recovery for children with mild TBI. Identification of different symptom trajectories and the influence of parental and family functioning as predictors of those trajectories provides guidance in developing family-based treatments and enabling the targeting of those treatments to children at risk for poor recovery.

Preface

This dissertation presents original work related to the association between parental and family functioning and post-concussive symptoms (PCS) after pediatric mild traumatic brain injury (TBI). Chapter 1 provides a general overview of pediatric mild TBI and parental and family functioning, as an introduction to provide background for the overall project. Chapters 2 and 3 present manuscripts for which L. Chadwick was the lead contributor (e.g., conceptualization, writing, data extraction, analysis, etc.). Chapter 2 describes Study 1, a scoping review investigating the relation between parental and family functioning and PCS after pediatric mild TBI. L. Chadwick was the lead author on this scoping review. Support for this project included search term development from an expert librarian (A.H.), second review of abstracts and full-text articles (M.G.M.), and manuscript review and editing (M.G.M., S.M., B.L.C., and K.O.Y.). A version of the manuscript described in Chapter 2 has been published as Chadwick et al. (2023), "The relation between parental and family functioning and post-concussive symptoms after pediatric mild traumatic brain injury: A scoping review." *Journal of Neurotrauma, 41*(3-4), 305-318. 10.1089/neu.2023.0201. In addition to Chapter 2, portions of the introductory and concluding texts are used with permission from Chadwick et al. (2023). Chapter 3 describes Study 2, an original research study investigating parental and family functioning as predictors of longitudinal trajectories of PCS after mild TBI and orthopedic injury (OI). This study drew on data from a larger parent study, the Advancing Concussion Assessment in Pediatrics study (A-CAP; Yeates et al., 2017). The A-CAP study received approval from the University of Calgary Conjoint Health Research Ethics Board (REB15-2296). L. Chadwick was the lead author of the manuscript presented in Chapter 3. Support for this project included manuscript review and editing (S.M., B.L.C., and K.O.Y.). Finally, Chapter 4 provides concluding remarks presenting a summary and integration of findings from Chapters 2 and 3, as well as a discussion of clinical implications and areas for further research.

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List of Abbreviations

Abbreviation	Definition
A-CAP	Advancing Concussion Assessment in Pediatrics
DSM	Diagnostic and Statistical Manual of Mental Disorders
ED	Emergency Department
GCS	Glasgow Coma Scale
ICD	International Classification of Disease
LOC	Loss of consciousness
MVC	Motor vehicle collision
OI	Orthopedic injury
PERC	Pediatric Emergency Research Canada
PCS	Post-concussive symptoms
PTA	Post-traumatic amnesia
TBI	Traumatic brain injury

Chapter 1: Introduction

Traumatic Brain Injury

Traumatic brain injury (TBI) is a pressing public health concern that results in Emergency Department (ED) visits, hospitalizations, disability, and death for hundreds of thousands of people every year (CDC, 2019). TBI is defined as "an alteration in brain function, or other evidence of brain pathology, caused by an external force" (Menon et al., 2010, p. 1637). This disruption in normal brain function can be caused by an external force to the head, face, neck, or elsewhere on the body, or when the brain undergoes sudden movement without direct external trauma (CDC, 2019). TBIs are graded on a continuum of severity including, mild, moderate, and severe, with the degree of impairment following TBI varying as a function of the severity of the injury (Carlozzi et al., 2013). Severity classification is typically based on level of consciousness assessed through ocular, verbal, and motor responses using the Glasgow Coma Scale (GCS; Teasdale & Jeanettte, 1974). Severe TBIs are characterized by significant impairment in consciousness (e.g., GCS $\leq$ 8), while mild TBIs are characterized by minor impairments (e.g., GCS=13-15).

Mild TBI, including concussion, is a common injury sustained by children and adolescents. They occur in at least one to two million children and adolescents in North America annually (Bryan et al., 2016); because many mild TBIs go undetected or do not receive medical attention, however, the true prevalence is likely much higher (McCrea et al., 2004). In Canada, reported pediatric mild TBIs increased by approximately 10% between 2003 and 2013, and continue to increase (Zemek et al., 2017). Notably, 70-90% of all diagnosed TBIs are classified as mild (i.e., involving a brief change in mental status; CDC, 2019), underscoring the fact that pediatric mild TBI poses a significant public health burden (Cassidy et al., 2004). The Centers for Disease Control and Prevention, World Health Organization, National Institutes of Health, and Canadian Institutes for Health Research have all called for more research on pediatric mild TBI to promote the delivery of evidence-informed care.

Post-concussive Symptoms

Mild TBI often result in physical (e.g., headache, dizziness), cognitive (e.g., inattention, forgetfulness), and emotional (e.g., irritability, dysphoria) complaints, known collectively as post-concussive symptoms (PCS; Barlow, 2016; Taylor et al., 2010). PCS are most severe immediately following an injury and typically resolve within one to three months (Barlow et al., 2010), with 33% of children experiencing PCS for at least 1-month post-injury (Chadwick et al., 2022) and 15% remaining symptomatic for three months (Zemek et al., 2016). Although most children who sustain a mild TBI recover fully, a subset are hindered by PCS that persist beyond 3-months post-injury and that reduce their quality of life (Barlow et al., 2010). The presence of PCS, even if only for several weeks, can cause disruptions in children's daily activities, academic performance, family functioning, and long-term psychosocial adjustment (Moran et al., 2012).

Injury-related verses Noninjury-related Risk Factors

The development of and recovery from many medical and psychological conditions can be understood through the biopsychosocial model of health, which acknowledges the overlap and interaction of biological (e.g., physical health, genetic vulnerabilities), psychological (e.g., coping skills, personality), and social (e.g., family environment, relationships) factors (Engel, 1977). In the case of mild TBI, recovery can be influenced by both injury-related factors (e.g., injury severity, mechanism of injury) and noninjury-related factors (e.g., age, coping strategies). Interestingly, noninjury-related factors often explain relatively more variability in mild TBI outcomes (Luis et al., 2003; Ponsford et al., 1999). This is important because noninjury-related factors may be more modifiable than injury-related factors and, for that reason, may make better targets for post-injury treatment. Previous research has identified a variety of noninjury-related family factors that are related to outcomes following TBI; however, the research examining the impact of noninjury-related factors, such as parental and family functioning, on TBI recovery tends to focus on the more severe end of the TBI spectrum. These factors have not been examined in detail in pediatric mild TBI, so the importance of parenting and the family environment to mild TBI recovery remains unclear. With mild TBI accounting for the majority of all TBI-related ED visits (CDC, 2014), the importance of identifying symptom recovery trajectories and factors than can be targeted for intervention after mild TBI can not be understated.

Parent and Family Factors

Bronfenbrenner's ecological systems theory suggests that child development is influenced by interconnected environmental systems, which include the microsystem, mesosystem, exosystem, macrosystem, and chronosystem (Bronfenbrenner, 1977). The microsystem includes a child's immediate family and school environments and can be considered the most influential system on an individual's development. Parents and the broader family unit have immediate and direct contact with children and play an important role in their everyday interactions. Parents are also critically important during children's recovery from injury and an extensive literature documents the reciprocal relationship between family functioning and outcomes of childhood TBI (Beauchamp et al., 2021; Rashid et al., 2014). While parental and family factors have been shown to influence recovery from pediatric mild TBI, many of the findings have been mixed, and the unique factors involved and the strength and direction of each relationship to symptom recovery deserves further investigation (Rigney et al., 2023).

Family Functioning

General family functioning appears to moderate outcomes after TBI, such that more favourable family environments are associated with more positive outcomes, including better behavioural adjustment (Taylor et al., 2002), academic performance (Taylor et al., 2002), and social functioning (Ryan et al., 2016; Yeates et al., 2010). Taylor and colleagues (2002) prospectively followed a sample of children with moderate to severe TBI for up to four years post-injury. The researchers examined the relationship between the family environment, which included measures of socioeconomic status, maternal education, family income, stressors and resources, children's behaviour problems, and school performance post-injury. They found children from more advantaged backgrounds had more positive long-term behavioural and academic outcomes compared to children from disadvantaged backgrounds, relative to children with orthopedic injuries (OI). Pediatric TBI has also been associated with reduced social engagement and poor social adjustment (Anderson et al., 2013). Interestingly, parental and family functioning may explain a significant proportion of the variance in social problems following TBI (Ryan et al., 2016; Yeates et al., 2010). Ryan and colleagues (2016) found that poorer family functioning and caregiver mental health were associated with an increase in social problems 12 to 24 months after severe TBI.

In the context of mild TBI, Yeates et al. (2012) prospectively examined premorbid family functioning as a predictor of PCS in 8- to 15-year-old children. Contrary to expectations based on findings from research in severe TBI, they found that parents from families with higher functioning reported more pronounced somatic PCS in their children after injury. Interestingly, these findings suggest that children from higher functioning families may actually be more sensitive to mild TBI (Yeates et al., 2012). Another possibility is that parents from higher functioning families with more resources are more attentive and thus more likely to perceive changes in their child's health status compared to parents from lower functioning families. Although good family functioning may buffer against the adverse effects of moderate to severe TBI, few studies have investigated the association between family functioning and outcomes in mild TBI. Further examination of family functioning in a large, prospective sample of children and their families is warranted to deepen the understanding of its influence on mild TBI outcomes.

Parental Psychological Adjustment

Parental psychological adjustment has been linked to pediatric TBI risk and outcome. Children whose parents report mental health problems, such as mood, personality, or behavioural disorders, are at a significantly increased risk of sustaining TBI (Lowery Wilson et al., 2019). Parental psychological functioning is also associated with outcomes after TBI, such that poor parental adjustment is associated with more child behavioural problems (Raj et al., 2014), and higher levels of parental distress at 6-months post-injury predicts more child behavioural problems at 12-months post-injury (Taylor et al., 2001). Higher levels of parental distress are related to an authoritarian parenting style, both of which are associated with lower adaptive functioning in children with moderate and severe TBI (Micklewright et al., 2012).

Parental psychological adjustment also impacts parents' reporting of their child's PCS after mild TBI. McNally et al. (2013) found that more parental distress predicted more parent- but not child-reported symptoms at most time points. The relationship between parental psychological adjustment and pediatric TBI outcomes is likely reciprocal, as parents' psychological state influences how they react to their child's injury and is also influenced by the injury, such that parents of injured children are more likely to be distressed or to develop mental health concerns (Beauchamp et al., 2021). Rigney and colleagues (2023) hypothesized that parental psychiatric comorbidities may influence children's recovery from mild TBI in several ways, such as by interfering with parents' ability to care for an injured child, interfering with parents ability to recognize PCS as abnormal because symptoms commonly associated with mild TBI may be regularly experienced by the parent, or by children inheriting a biological vulnerability from their parents that predisposes them to experience more PCS compared to their peers. To date, few studies have specifically examined the relationship between parental psychological adjustment and children's recovery after mild TBI.

Parental Responses to Children's Symptoms

The way parents perceive and respond to their child's symptom complaints after an injury sets the course for their child's recovery trajectory (Beauchamp et al., 2021). For example, higher levels of protective parental behaviour, such as restricting activities due to pain, is associated with higher levels of children's somatic pain symptoms (Claar et al., 2008), as well as parental distress (Sieberg et al., 2011). In a study of adolescents/young adults (i.e., 14- to 24-year-olds) who sustained a concussion and their parents, overparenting was significantly related to longer recovery times, as well as higher anxiety and stress in the adolescent post-injury (Trbovich et al., 2022). In this study, overparenting practices were defined as overly involved, protective, and low in autonomy (Trbovich et al., 2022). Further, parental detection of their child's PCS after early childhood mild TBI (i.e., ages 1-5) is associated with higher quality parent-child interactions (Lalonde et al., 2020). This suggests that a well-adjusted and adaptive response from parents after mild TBI may facilitate positive outcomes (Beauchamp et al., 2021).

However, further investigation is needed to delineate the effects of parental responses on cognitive and somatic PCS recovery trajectories after mild TBI for children of all ages.

Social Support from Parents

Social support is defined as the psychological and material resources available to an individual (Dunne et al., 2019). Social support is typically categorized as emotional (e.g., behaviour, such as empathy and affection, that assures an individual that they are loved and valued; Cobb, 1976); informational (e.g., communication of knowledge and facts, such as providing advice, guidance, and feedback; Cutrona & Suhr, 1992); or instrumental (e.g., tangible assistance, such as providing needed goods and services; Cutrona & Suhr, 1992). Additionally, perceived social support can be differentiated from received social support in that perceived support involves one's perception of the general support available to them or specific supportive behaviours from individuals in their social network (Malecki & Demaray, 2002), whereas received support involves the actual receipt of supportive behaviours (Haber et al., 2007). The present project focuses on the construct of perceived support because it has been consistently linked to positive mental and physical health outcomes for children and adolescents (Malecki & Demaray, 2002). In general, higher levels of perceived social support protect against a range of detrimental consequences, while lower levels of support are associated with more negative outcomes (Malecki & Demaray, 2002).

Although the relationship between social support and health has been widely researched, few studies to date have examined the influence of social support on pediatric mild, moderate, or severe TBI outcomes, with most of the relevant studies employing qualitative research methods in samples comprised only of individuals injured in sport-related settings. In a recent qualitative study, Kita and colleagues (2020) found that adolescent girls recovering from sport-related concussions reported that social support from different sources (i.e., close friends, peers with a history of concussion, and parents) was important for their recovery and that support from each source was valued differently. No study has quantitatively investigated the specific influence of parental social support on pediatric mild TBI symptom recovery. Social support from parents may play an important role in recovery for children and adolescents with mild TBI by decreasing their anxiety (Covassin et al., 2014) and providing understanding and validation about the difficulties experienced during recovery (Snell et al., 2017).

Overall, a considerable body of evidence suggests that noninjury-related factors play an important role in recovery from TBI. Although research has been conducted on the influence of parental and family functioning on pediatric TBI outcomes, this has been primarily in the context of moderate and severe TBI. The prevalence of mild TBI far outweighs that of more severe TBI, so further investigation into the impact of the family environment on mild TBI recovery will be crucial to deepen our understanding of parental and family influences and will provide evidence critical to developing family-based interventions for mild TBI.

Study Rationale

Broadly, the goal of this dissertation was to examine the influence of parental and family functioning on PCS recovery trajectories after mild TBI. This dissertation presents two separate but related studies. The first study is a scoping review that examined the existing research on the relationship between parental and family functioning and pediatric mild TBI to determine relevant parent and family factors, summarize findings, and identify areas for further research. This formal scoping review ensured that relevant studies were not overlooked.

The second study is an original research study that aimed to identify different trajectories of child- and parent-reported PCS after mild TBI in 8- to 16-year-old children and to examine their association with parental and family functioning across the first 6-months post-injury, as compared to children with OI. Parental and family factors, such as global family functioning, social support provided by parents, parental psychological adjustment, and parental responses to children's symptoms, are likely interrelated and may jointly influence children's recovery from mild TBI. In this context, a novel statistical technique called group-based multi-trajectory modeling could provide a more complete, accurate, and clinically relevant characterization of individual mild TBI outcomes over time. This study drew on data from a larger parent study, the Advancing Concussion Assessment in Pediatrics study (A-CAP; Yeates et al., 2017), which broadly examined outcomes after pediatric mild TBI in children and adolescents ages 8.00 to 16.99 years recruited from EDs of five Canadian pediatric hospital sites. A-CAP is the largest study of its kind to date, with a sample size of 644 participants in the mild TBI group and 339 in the OI control group (Yeates et al., 2017).

Collectively, these studies represent novel contributions to research examining the influence of parental and family functioning on PCS recovery trajectories after pediatric mild TBI. Identification of different symptom trajectories and the influence of parental and family functioning as predictors of those trajectories will provide guidance in developing family-based treatments and enabling the targeting of those treatments to children at risk for poor recovery.

Chapter 2: Study 1

The Relation Between Parental and Family Functioning and Post-concussive Symptoms after Pediatric Mild Traumatic Brain Injury: A Scoping Review

Abstract

This scoping review aimed to address the following questions: (1) Does mild traumatic brain injury (TBI) result in more parental distress or poorer family functioning than other injuries?; (2) Does pre-injury or acute parental distress and family functioning predict post-concussive symptoms (PCS) after mild TBI?; and (3) Does acute PCS predict later parental distress and family functioning? Children/adolescents sustained mild TBI before age 18 and underwent assessment of PCS and parent or family functioning. MEDLINE, PsycINFO, CINAHL, Embase, and CENTRAL databases were searched to identify original, empirical, peer-reviewed research published in English. PCS measures included parent- and child-reported symptom counts and continuous scales. Parent and family measures assessed parental stress, psychological adjustment, anxiety, psychiatric history, parent-child interactions, family burden, and general family functioning. A total of 11,163 articles were screened, leading to the inclusion of 15 studies, with 2,569 participants (mild TBI n = 2,222; control n = 347). Collectively, the included articles suggest that mild TBI may not result in greater parental distress or poorer family functioning than other types of injuries. Pre-injury or acute parental and family functioning appears to predict subsequent PCS after mild TBI, depending on the specific family characteristic studied. Early PCS may also predict subsequent parental and family functioning, although findings were mixed in terms of predicting more positive or negative family outcomes. The available evidence suggests that parent and family functioning may have an important, perhaps bidirectional, association with PCS after pediatric mild TBI. However, further research is needed to provide a more thorough understanding of this association.

Introduction

Mild traumatic brain injury (TBI; e.g., concussion) affects at least one million children in the United States annually (Bryan et al., 2016), and can cause a constellation of somatic, cognitive, and affective complaints, collectively known as post-concussive symptoms (PCS; Taylor et al., 2010). PCS are most pronounced immediately after injury and typically resolve within one month, but persist longer in 25-35% of cases (Barlow et al., 2010; Chadwick et al., 2022; Zemek et al., 2016). Although systematic reviews report limited long-term impairments after mild TBI in children (Babikian & Asarnow, 2009; Lloyd et al., 2014), some children show longitudinal post-injury trajectories after pediatric mild TBI involving high acute and persistent PCS (Yeates et al., 2009). Such findings reveal a gap in our understanding of recovery after pediatric mild TBI and highlight the need for further investigation.

Both injury-related factors (e.g., injury severity, mechanism of injury) and noninjury-related factors (e.g., age, sex, coping strategies) are associated with mild TBI recovery, with previous research suggesting that noninjury-related factors may be stronger predictors of post-injury outcomes (Luis et al., 2003; Ponsford et al., 1999). Specifically, parental and familial factors contribute to and are affected by children's recovery after TBI (Beauchamp et al., 2021; Rashid et al., 2014; Taylor et al., 2001). For example, worse outcomes in children with moderate to severe TBI relative to those with orthopedic injuries (OI) have been associated with worse family environments (i.e., lower socioeconomic status, maternal education, family income, and more stressors; Taylor et al., 2002), poor parental psychological functioning (Raj et al., 2014), and higher parental distress (Taylor et al., 2001).

Previous research has mostly focused on parental and family factors in relation to moderate to severe TBI. Interestingly, one study of children with mild TBI found that higher premorbid family functioning predicted more pronounced PCS (Yeates et al., 2012), suggesting that family functioning may play a different role in pediatric mild TBI recovery compared to that seen in moderate and severe TBI. However, no previous review has focused on the role of parent and family functioning in children's recovery from mild TBI. Although our understanding of how parents and families affect children's outcomes after mild TBI is limited, research exploring this critical question is emerging. Because noninjury-related factors may be more modifiable than injury-related factors, they are promising targets of post-injury treatment and intervention, and therefore merit review. The aim of this scoping review was to summarize extant evidence on the relation between parental and family factors and children's outcomes after mild TBI, with a particular focus on PCS. Specifically, this review addresses the following questions:

(1) Does mild TBI result in more parental distress or poorer family functioning than other injuries?

(2) Does pre-injury or acute parental distress and family functioning predict PCS after mild TBI, and, if so, do they serve as moderators of the effect of mild TBI?

(3) Does early PCS predict later parental distress and family functioning? In other words, do PCS and parental distress/family functioning have a bidirectional relationship?

Methods

The review process followed the methodological framework for scoping reviews developed by Arksey and O'Malley (2005), which involves: (1) identifying the research question; (2) identifying relevant studies through a search of the literature; (3) selecting relevant studies for review; (4) charting the data; and (5) collating, summarizing, and reporting the results. The authors used the Preferred Reporting Items for Systematic Reviews and Meta-

Analyses checklist extension for scoping reviews (PRISMA-ScR; Tricco et al., 2009) to structure the review. A review protocol was developed but not registered for this study.

Search Strategy

A librarian created a search strategy using keywords related to pediatric concussion/mild TBI, PCS, and parent/family factors. The search strategy was initially developed and tested in MEDLINE Ovid, then adapted for use in the other databases. Initial searches were conducted on July 13, 2021, in MEDLINE, PsycINFO, CINAHL, Embase, and CENTRAL databases, and were updated on July 4, 2023. Table 1 provides an example of the search terms used in MEDLINE. The full list of search terms for each database is presented in Appendix A. Searches were filtered to only include human participants and studies published in English. No restriction was placed on publication year. Titles and abstracts were exported to Covidence, a web-based systematic review management software (Veritas Health Information, n.d.). Other articles of interest were identified by searching the reference lists of relevant articles.

Table 1

MEDLINE Search Strategy

Research Concept	Search Terms
#1 Concussion/mild traumatic brain injury	Exp Brain Concussion/ Exp Brain Injuries/ (concussion* or concussed or concussive or subconcuss* or sub-concuss*).tw,kw. (Mild adj3 (traumatic brain injur* or tbi*)).tw,kw. mtbi*.tw,kw. (Head adj2 (injur* or impact* or trauma*)).tw,kw. (Traumatic brain injur* or tbi*).tw,kw. (Neurotrauma* or neuro-trauma*).tw,kw. (Craniocerebral adj2 (trauma* or injur*)).tw,kw. Brain contus*.tw,kw.
#2 Parents and family	Exp Family/ Exp Caregivers/ Exp Parents/ Family factors.tw,kw. (family or families).tw,kw. (parent* or parent-child interact* or dyad).tw,kw. (mother* or mom or moms or maternal or father* or dad or dads or paternal or brother or sister or sibling*).tw,kw.
#3 Symptom recovery	Exp Prognosis/ Exp Behavioral Symptoms/ (recover* or prognosis or symptom* or outcome* or postconcussi* or post-concussi*).tw,kw. (return to or return-to adj2 (play* or school* or learn*)).tw,kw.
#4 Mild traumatic brain injury AND parents and family AND symptom recovery	1 AND 2 AND 3

Study Eligibility

Inclusion criteria were as follows: (1) participants sustained concussion/mild TBI on or before the age of 18; (2) symptoms after injury were documented (using questionnaire or objective measures); (3) parental and/or family functioning was assessed; (4) studies were peer-reviewed cohort studies, clinical trials, case studies, or case control studies; and (5) available in English. Studies that reported on a range of injury severities (i.e., moderate and severe TBI) but that categorized mild TBI as a distinct subgroup were not excluded. Participants with a history of multiple childhood concussions or mild TBIs were not excluded. Studies that included injuries classified as complicated mild TBI (i.e., with accompanying intracranial abnormalities or skull fractures; McNally et al., 2013) but did not categorize uncomplicated mild TBI as a distinct subgroup were excluded. Review articles, conference abstracts, books/chapters, editorials, and opinion articles were excluded.

Study Screening and Data Extraction

Study team members LC and MGM conducted the title and abstract review, full-text review, and data extraction. LC and MGM achieved interrater agreement >90% on a random sample of 100 abstracts before conducting the review. Any discrepancies were resolved through consensus between LC and MGM. Data extracted included study characteristics (e.g., study location, study design, recruitment methods), PCS/recovery definition, participant demographic information, parental/family functioning assessment method, child symptom assessment method, and study findings.

Figure 1 details the database search and article screening process. The database search resulted in a total of 17,558 records. Two additional studies were identified by searching the reference lists of articles identified through the database search. After the removal of duplicate records, 11,163 records were reviewed at the title and abstract screening stage. Following title/abstract review, 223 studies were assessed for eligibility. During full-text review, 208 studies were excluded for not meeting the scoping review's inclusion criteria, resulting in 15 studies that were included for review. Full-text articles were most frequently excluded for having inappropriate participants (e.g., moderate or severe TBI, mild TBI sustained after age 18). The results of the 15 included studies were synthesized and summarized. We did not conduct a meta-analysis because of the heterogeneity of the outcomes in the included studies.

Results

Study characteristics for the 15 included studies (mild TBI *n* = 2,222; control *n* = 347) are presented in Table 2.

Figure 1

Literature Review and Article Screening Process

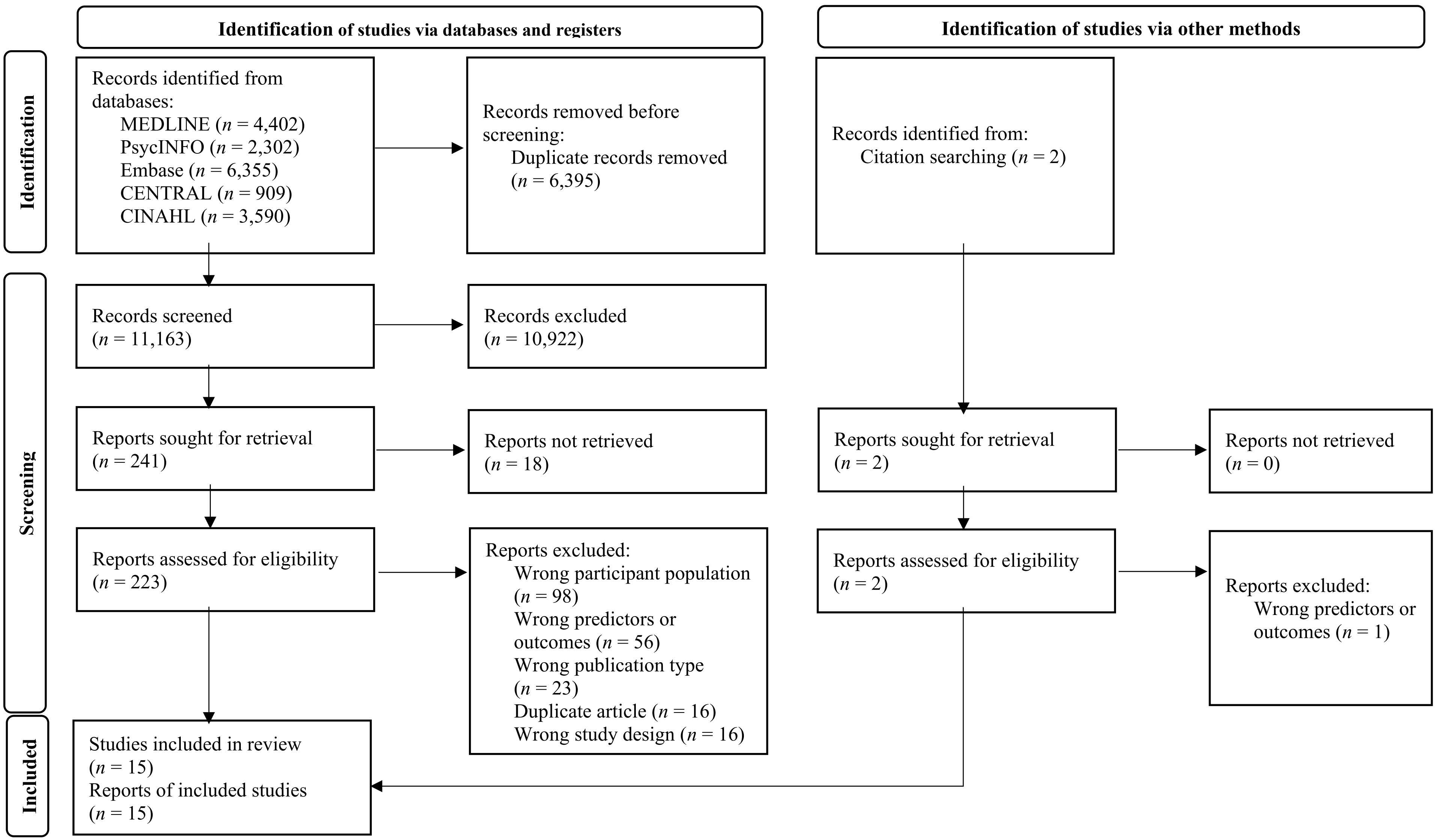


Table 2

Overview of Studies Included in the Scoping Review

First Author & Year	**Location**	**Study Design**	**Mild TBI Sample Size (*n*)**	**Mild TBI Sample Age (years)**	**Mild TBI Sample Sex (% male)**	**Injury Diagnosis**	**Time Post-Injury at Enrollment**	**Participant Recruitment**
Barlow, 2010	Calgary, Canada*	Prospective cohort	670	*M*=7.62 *SD*=5.61 Range= 0.01-17.9	57.5%	Mild TBI	7-10 days	Retrospective search of recent ED admissions
Bernard, 2016	Melbourne, Australia	Prospective cohort	46	*M*=0.63 (7.5 months) *SD*=0.24 (2.9 months)	63%	Mild TBI	<48 hours	ED presentation & retrospective search of recent admissions
Bernard, 2020	Melbourne, Australia	Prospective longitudinal cohort	31	*M*=7.73 (92.7 months), *SD*=2.93 (35.1 months)	58.1%	Mild TBI	8-41 months (*M* = 24.29, median = 25.00)	ED presentation & retrospective search of recent admissions
Ewing-Cobbs, 2018	Houston & Salt Lake City, USA	Prospective longitudinal cohort	119	*M*=10.3, *SD*=3.7	63%	Mild TBI	Not reported	ED recruitment
Ganesalingam, 2008	Columbus & Cleveland, USA	Prospective longitudinal	181	No LOC: *M*=39.03 (*SD*=19.13)LOC: *M*=39.32 (*SD*=18.00)	Total: 71.8% (No LOC: 68.2%; LOC: 77.5%)	Mild TBI	Not reported (days at baseline assessment *M*=11.19, *SD*=3.62)	Consecutive admissions to ED
Lalonde, 2020	Montreal, Canada	Prospective longitudinal cohort	68	*M*=3.49 (41.9 months), *SD*=0.95 (11.4 months)	56%	Mild TBI	Not reported	Consecutive admissions to ED

Legarreta, 2018	Tennessee, USA	Retrospective cohort	154	FPH only: *M*=15.8 (*SD*=1.02); FPH/PPH: *M*=14.92 (*SD*=1.04); Control: *M*=14.73 (*SD*=1.31)	55.8%	Concussion	6 weeks (not specified, but inclusion criterion for persistent symptom duration)	Presentation at sports concussion center for post-concussion evaluation
McNally, 2013	Columbus & Cleveland, USA	Prospective longitudinal	186	LOC: *M*=12.15 (*SD*=2.20); no LOC: *M*=11.83 (*SD*=2.23)	Total: 70.96% (LOC: 77.02%; no LOC: 66.96%)	Mild TBI	Not reported	Consecutive ED admissions
Morgan, 2015	Tennessee, USA	Retrospective, case-control	120	PCS: *M*=14.9 (*SD*=2.1); control: *M*=14.8 (*SD*=2.0)	Total: 49.2% (PCS: 47.5%; control: 50.0%)	Concussion	Not reported	Specialized (concussion) clinic database
Olsson, 2013	Brisbane & Melbourne, Australia	Prospective longitudinal	Mild TBI (no imaging) = 71 uncomplicated mild TBI = 62	Mild TBI (no imaging): *M*=10.81 *(SD=2.46)* uncomplicated mild TBI: *M*=10.90 *(SD=2.33)*	Mild TBI (no imaging): 71.8% uncomplicated mild TBI: 73.8%	Mild TBI	Not reported	Consecutive ED admissions
Teel, 2022	Montreal, Canada*	Convergent mixed methods design	49	*M*=13.8, *SD*=2.3	75.9%	Concussion	Not reported	Specialized (concussion) clinic recruitment
Truss, 2020	Melbourne, Australia	Prospective longitudinal	169	*M*=11.17 (*SD*=3.2)	70.41%	Concussion	<48 hours	ED recruitment

Yeates, 2012	Columbus & Cleveland, USA	Prospective longitudinal cohort	186 (overlap with McNally sample)	No LOC: *M*=11.83, *SD*=2.23; LOC: *M*=12.15, *SD*=2.20	70.97%	Mild TBI	Not reported	Consecutive admissions to ED
Yumul, 2020	Christchurch, New Zealand	Cross-sectional	198	*M*=6.43 (*SD*=3.37)	60%	Mild TBI	≤1 week of ED visit	Identification from ED admissions
Zemek, 2013	Ottawa, Canada	Prospective observational cohort	98	*M*=12 (*SD*=3)	58%	Concussion	<48 hours	ED recruitment

Note. *Location of corresponding author; ED = Emergency Department; LOC = loss of consciousness.

Question 1: Does mild TBI result in more parental distress or poorer family functioning than other injuries?

Key findings are presented in Table 3. The first question of the scoping review sought to understand the influence of injury type on parental and family functioning. Three included studies assessed parental and family functioning after mild TBI compared to children with other injuries, including extracranial injuries (Barlow et al., 2010), OI (Ganesalingam et al., 2008), and superficial injuries to the head (Yumul et al., 2020).

Yumul et al. (2020) conducted a cross-sectional analysis of data from a larger prospective longitudinal study. They administered the Parenting Stress Index-Short Form (PSI-Short Form; Abidin, 2012), a self-reported measure of parenting-related stress, within 2-weeks post-injury. They reported no difference in parental stress between their mild TBI group and the superficial head injury group ($p = 0.56$, $d = 0.09$) within 2-weeks after injury (Yumul et al., 2020).

Barlow et al. (2010) conducted a prospective, consecutive controlled-cohort study of children who presented to an ED. They administered the General Functioning Scale of the McMaster Family Assessment Device (FAD-GF; Byles et al., 1988) and the Brief Symptom Inventory (BSI; Derogatis & Melisaratos, 1983). The General Functioning subscale consists of 12 items that measure overall family health/pathology. The BSI is a self-report measure of a variety of psychological symptoms. Parents of injured children completed the FAD-GF and the BSI 1-month post-injury. Barlow et al. (2010) reported no significant difference in overall family functioning between the mild TBI group and the extracranial injury group at 1-month post-injury ($p = 0.55$, $d = 0.11$). Maternal psychological adjustment, as measured by the BSI, also did not significantly differ between the mild TBI group and the extracranial injury group in terms of both distress (p = 0.91, d = 0.24) and symptom intensity (p = 0.06, d = 0.55) at 1-month post-injury (Barlow et al., 2010).

Ganesalingam et al. (2008) conducted a prospective longitudinal study of children presenting to an ED. They administered the BSI and the Family Burden of Injury Interview (FBII; Burgess et al., 1999). The FBII measures stress experienced by families after a child's injury, including concerns about the child's adjustment and recovery, reactions of extended family members and friends, reactions of the spouse and sibling(s), and changes in family routine (Ganesalingam et al., 2008). Both the BSI and FBII were completed by parents acutely and at 3-months post-injury. Ganesalingam et al. (2008) examined children with mild TBI without loss of consciousness (LOC) separately from children with mild TBI with LOC. After controlling for family socioeconomic status and premorbid family functioning, Ganesalingam et al. (2008) reported no significant difference between the mild TBI without LOC group and the OI group in parental distress (as reported by the Global Severity Index of the BSI; p = 0.71, d = 0.05) or family burden (p = 0.48, d = 0.10) across the first 3-months post-injury. However, they found the mild TBI with LOC group reported greater family burden (p = 0.04, d = 0.37) compared to the OI group at 3-months post-injury (Ganesalingam et al., 2008).

In sum, these three studies did not report significant differences in parental or family functioning after injury between the mild TBI and comparison groups, except for one result when mild TBI with LOC was analyzed separately. Although the domains of parental and family functioning assessed, the type of comparison group, and the time post-injury varied between studies, the results tentatively suggest that mild TBI may not result in greater parental distress or poorer family functioning than other types of injuries, except perhaps in the case of more severe injuries, such as those accompanied by LOC.

Question 2: Does pre-injury or acute parental distress and family functioning predict PCS after mild TBI? If so, do they act as moderators?

The second question aimed to better understand the influence of pre-injury and acute parental and family functioning on later PCS after mild TBI. Twelve studies assessed parental or family functioning either pre-injury or in the acute period after injury.

McNally et al. (2013) conducted a prospective longitudinal study of children presenting to an ED. They assessed pre-injury parental and family functioning with the FAD-GF, the BSI, and the Life Stressors and Social Resources Inventory (LSSRI; Moos & Moos, 1988, 1994). The LSSRI is an interview measure that assesses stressors and resources, producing standard scores, across a range of domains. Parent- and child-reported PCS ratings were collected across the first 12-months post-injury using the Health and Behavior Inventory (HBI; Yeates et al., 1999) and the Post-Concussive Symptom Interview (Mittenberg et al., 1997). McNally et al. (2013) reported pre-injury parental distress on the BSI predicted parent-reported symptom counts on the Post-Concussive Symptom Interview post-acutely ($p < 0.05$, $\beta = 0.25$), 1-month ($p < 0.05$, $\beta = 0.20$), and 12-months post-injury ($p < 0.05$, $\beta = 0.15$). Pre-injury family stressors ($p < 0.05$, $\beta = 0.14$) and resources ($p < 0.05$, $\beta = 0.14$) on the LSSRI predicted parent-reported symptom counts on the PCS-I at 3-months post-injury. However, pre-injury family factors were not related to child-reported symptom counts on the Post-Concussive Symptom Interview at any time. Parental distress on the BSI predicted parent-reported somatic symptoms on the HBI post-acutely ($p < 0.05$, $\beta = 0.19$), 1-month ($p < 0.05$, $\beta = 0.24$), and 12-months post-injury ($p < 0.05$, $\beta = 0.13$). Stressors on the LSSRI predicted parent-reported somatic symptoms on the HBI post-acutely ($p < 0.05$, $\beta = 0.12$) and 3-months post-injury ($p < 0.05$, $\beta = 0.21$). However, pre-injury family factors were not associated with child-reported somatic symptoms on the HBI at any time.

McNally et al. (2013) also reported that pre-injury parental distress on the BSI predicted parent-reported cognitive symptoms on the HBI post-acutely ($p < 0.05$, $\beta = 0.19$), 1-month ($p < 0.05$, $\beta = 0.13$), and 3-months post-injury ($p < 0.05$, $\beta = 0.12$). Family stressors and resources on the LSSRI did not predict parent- or child-reported cognitive symptoms on the HBI at any time. Pre-injury family functioning on the FAD-GF did not predict parent- or child-reported symptom counts on the Post-Concussive Symptom Interview or somatic or cognitive symptoms on the HBI at any time (McNally et al., 2013).

Yeates et al. (2012) examined children from the same cohort reported by McNally et al. (2013) but sought to determine whether pre-injury family functioning moderated group differences in PCS after mild TBI. Yeates et al. (2012) reported that parent-reported somatic symptoms on the HBI showed evidence of moderation by family functioning, such that symptoms were more pronounced in children from higher functioning families ($p = 0.002$, $d = 12.40$) and who had more resources ($p = 0.001$, $d = 13.48$).

Ewing-Cobbs et al. (2018) conducted a prospective longitudinal cohort study of children presenting to EDs. They assessed pre-injury family functioning with the FAD-GF. PCS were assessed with the Postconcussion Symptom Inventory-Parent scale (PCSI-Parent; Sady, Vaughan, & Gioia, 2014) at ED presentation (to provide retrospective ratings of pre-injury PCS) and 3-, 6-, and 12-months post-injury. The PCSI-Parent provides a total symptom score and physical, cognitive, emotional, and fatigue sub-scores. Ewing-Cobbs et al. (2018) reported poorer pre-injury family functioning predicted greater emotional ($p < .001$) and cognitive symptoms ($p = 0.046$), and children with poorer functioning families were at greater risk for chronic symptoms at 1-year post-injury, even after adjusting for pre-injury PCS (OR = 2.42, 95% CI [1.23, 4.74], $p = 0.01$).

Truss et al. (2020) conducted a prospective longitudinal study of children presenting to an ED. They administered the Kessler Psychological Distress Scale (K10; Kessler et al., 2002) at 2-weeks post-injury, which measures psychological distress experienced over the previous month. PCS were measured with the PCSI-Parent. Truss et al. (2020) identified different symptom trajectory groups, based on parent-reported PCS up to 3-months post-injury. They reported that greater pre-injury and acute parental psychological distress increased the odds of children subsequently experiencing severe and persistent PCS (OR = 1.24, 95% CI [1.08, 1.42], p = 0.002; Truss et al., 2020).

Legarreta et al. (2018) conducted a retrospective cohort study of high school athletes who sustained a sport-related concussion. Participants' family psychiatric history was assessed through a clinical interview with a neuropsychologist and corroboration by an adult family member. PCS were measured with the self-reported Post-concussion Symptom Scale (PCSS; Lovell et al., 2006) and medical record notes at 6-weeks post-injury. Legarreta et al. (2018) reported concussed high school athletes with a family psychiatric history were over 2.5 times more likely to exhibit PCS than those without a family psychiatric history (OR = 2.52, 95% CI [1.20, 5.30], p = 0.03). Individuals with a family history of anxiety (OR = 2.99, 95% CI [1.36, 6.49], p = 0.02) or bipolar disorder (OR = 2.74, 95% CI [1.14. 6.67], p = 0.04) were specifically at increased risk of subsequent PCS after injury (Legarreta et al., 2018).

Morgan et al. (2015) also examined family psychiatric history through a retrospective review of the medical records of high school athletes who sustained a sport-related concussion. PCS was assessed with the PCSS. Morgan et al. (2015) found athletes with a family history of mood disorders (OR = 3.1, 95% CI [1.1, 8.5], p = 0.026) were more likely to develop PCS at 3-months post-injury than those without such a family history.

Teel et al. (2022) conducted a mixed methods study to investigate children's recovery after presenting to a specialized concussion clinic. They administered the Perceived Stress Scale (PSS-10; Lee, 2012) to assess the degree to which parents felt that situations were unpredictable or uncontrollable after their child's injury and the Child-Parent Relationship Scale (CPRS; Driscoll & Pianta, 2011), a measure of closeness, dependence, and conflict in the child-parent relationship, at 1- to 2-weeks post-injury. Parents also self-reported a history of premorbid mental health conditions, such as anxiety. PCS were assessed using the PCSI until discharge from the clinic, which occurred when a child displayed complete symptom resolution. Parent-child closeness was treated as a covariate in analyses of the association of parental stress with children's PCS. Teel et al. (2022) reported higher perceived parental stress at 1- to 2-weeks post-injury was related to significantly longer recovery time, measured by the number of days between the injury and clinic discharge (hazard ratio = 2.162, 95% CI [1.075, 4.348], $p = 0.03$), and time in clinic, measured by the number of days between clinic presentation and discharge (hazard ratio = 1.883, 95% CI [0.966, 3.668], $p = 0.06$). Premorbid parental anxiety was not found to be associated with either recovery time or time in clinic. In a clinical interview, parents described how their stress level varied over the course of their child's recovery and was directly related to their child's symptoms and overall functioning (Teel et al., 2022).

Yumul et al. (2020) assessed parental stress within 2-weeks post-injury using the PSI-Short Form. PCS were rated using the Rivermead Post-Concussion Symptoms Questionnaire (RPQ; King et al., 1995) at the time of injury and 3-months post-injury. They reported parental stress had significant predictive utility in determining parents' report of two or more symptoms at 3-months post-injury (OR = 1.03, 95% CI [1.00, 1.07], $p = 0.04$), with higher parental stress increasing the odds of parental report of PCS (Yumul et al., 2020).

Bernard et al. (2016) and Bernard et al. (2020) followed the same cohort of children with mild TBI but assessed PCS and parenting stress at different time points; Bernard et al. (2016) followed participants up to 3-months post-injury, while Bernard et al. (2020) began assessing participants at 8-months post-injury (follow-up occurred at an average of 23-months post-injury and ranged from 8 to 41 months). In both studies, pre-injury parenting stress was assessed with the PSI-Short Form. PCS were assessed with a list of symptoms from commonly used PCS scales, including the RPQ, Post-injury Symptom Checklist (Yeates et al., 2001), and the Acute Concussion Evaluation (Gioia, Collins, & Isquith, 2008). Higher pre-injury parental stress predicted greater PCS across the first 3-months post-injury (OR = 1.02, 95% [1.01, 1.04], $p = < 0.01$; Bernard et al., 2016), but did not predict PCS at or beyond 8-months post-injury (OR = 1.03, 95% CI [0.99, 1.07], $p = 0.19$; Bernard et al., 2020).

Olsson et al. (2013) analyzed a sub-sample of participants from a larger prospective study of children presenting to EDs. They considered children who underwent neuroimaging and whose results were normal or evidenced skull fractures limited to linear or basilar types only to have an 'uncomplicated mild TBI', while children whose injuries did not clinically warrant neuroimaging were coded as having a 'mild TBI (no imaging)'. They administered the General Health Questionnaire (GHQ; Goldberg & Williams, 1998), a measure of general mental health, at baseline (within 6-weeks post-injury) to assess pre-injury functioning. The researchers used parent's responses on the Child Behaviour Checklist (CBCL; Achenbach & Rescorla, 2001), which measures a variety of internalizing and externalizing symptoms, to derive a measure of PCS. PCS were measured at baseline, 6- and 18-months post-injury. Pre-injury parental depression predicted PCS at 6-months ($p = 0.001$, $\beta = 0.513$), but not at 18-months post-injury for children with uncomplicated mild TBI. Pre-injury parental anxiety did not predict PCS at 6-

months but did predict PCS at 18-months post-injury ($p < 0.001$, β = 0.851) for children with uncomplicated mild TBI, such that higher pre-injury parental anxiety was associated with more PCS. For children with mild TBI (no imaging), higher pre-injury parental anxiety was associated with fewer PCS at 6-months ($p = 0.023$, β = -0.432), but pre-injury parental anxiety did not predict PCS at 18-months. Pre-injury parental depression was not a significant predictor for children with mild TBI (no imaging; Olsson et al., 2013).

Zemek et al. (2013) conducted a prospective observational cohort study of children presenting to an ED. They assessed parental anxiety at the time of acute ED presentation and up to 3-months post-injury using the State-Trait Anxiety Inventory-State Anxiety Scale (STAI-S; Spielberg et al., 1983). PCS were assessed using the PCSI at 1-month post-injury. Parental anxiety at acute presentation (<48 hours post-injury) was not related to children's PCS 1-month post-injury (OR = 1.12, 95% CI [0.71, 1.75], $p = 0.63$), although anxiety was elevated in the parents of children who experienced prolonged symptoms (STAI-S median = 30, IQR = 22 to 44) compared to parents of children whose symptoms resolved before the 1-month follow-up (STAI-S median = 21, IQR = 20 to 45; Zemek et al., 2013).

Although the included studies varied in the domain of family functioning assessed and time post-injury, most studies reported that pre-injury or acute parental and family functioning predicted subsequent PCS in children after mild TBI. Four of the included studies, three of which examined parental anxiety, reported that some aspects of parental and family functioning did not predict later PCS (Bernard et al., 2020; Olsson et al., 2013; Teel et al., 2022; Zemek et al., 2013).

Question 3: Does early PCS predict later parental distress and family functioning?

The third question aimed to clarify whether early PCS predicts later parental and family functioning. In other words, if acute parental and family functioning predict later PCS, does the reverse also hold, suggesting a bidirectional relationship between PCS and parental and family functioning? Two studies included in the review assessed the association of early PCS with later parental and family functioning after mild TBI.

Lalonde et al. (2020) conducted a prospective longitudinal cohort study of children presenting to an ED. They administered an adaptation of the Mutually Responsive Orientation scale (MRO; Aksan et al., 2006; Kochanska et al., 2008), which consists of three subscales: Harmonious Communication, Mutual Cooperation, and Emotional Ambiance, at 6-months post-injury. The MRO focuses on the dyadic nature of parent–child exchanges. PCS were assessed with the parent-reported Post-Concussive Symptom Interview. Lalonde et al. (2020) reported acute PCS were a significant independent predictor of parent-child interactions in a snack-centered activity ($p = 0.089$, $d = 0.43$ [significant p-level < 0.20]) and a toy-centered activity ($p = 0.175$, $d = 0.37$ [significant p-level < 0.20]) at 6-months post-injury, such that children with more PCS displayed better parent-child interactions. These findings were interpreted to suggest that parents are likely to become more vigilant to their child's needs if they perceive their child as being more symptomatic following mild TBI, resulting in parents who are more responsive and attentive to their injured child (Lalonde et al., 2020).

Ganesalingam et al. (2008) investigated whether PCS measured shortly after injury were a predictor of parental distress and family burden, measured with the BSI and FBII, respectively, across 3-months post-injury. Parent- and child-reported PCS were measured at baseline with the Post-Concussive Symptoms Interview and the HBI. Ganesalingam et al. (2008) reported higher levels of parent-reported PCS on both the Post-Concussive Symptoms Interview and HBI shortly after injury predicted higher ratings of parental distress and family burden at 3-months post-injury. Higher levels of child-reported PCS at baseline predicted only more parental distress at 3-

months post-injury. The relation between PCS and family burden was stronger at the baseline assessment for the parent-rated Post-Concussive Symptoms Interview ($p = 0.001$, $d = 1.16$) than at 3-months post-injury ($p = 0.001$, $d = 0.45$). Thus, differences in family burden for children with high compared to low levels of early PCS tended to decrease over time (Ganesalingam et al., 2008).

Few studies investigated PCS as a predictor of later parental and family functioning. The two included studies reported that early PCS may predict later parental and family functioning, but the findings were mixed in terms of whether greater PCS predict more positive or negative family outcomes.

Table 3

Assessment of PCS and Parental/Family Functioning

First Author & Year	Research Question	PCS/Recovery Definition	PCS Measures	PCS Assessment Timepoint(s)	Family Domain Assessed	Family Measures	Family Assessment Timepoint(s)	Key Findings
Barlow, 2010	Q1	Symptom resolution (i.e., when parents reported no change from pre-injury and the scores for all symptoms were back to or below pre-injury levels)	PCS-I, RPQ	ED presentation, 2-weeks post-injury & monthly until symptom resolution	Family functioning, maternal psychological adjustment	FAD-GF, BSI	1-, 6-, & 12-months post-injury	• Family functioning (p = 0.55, d = 0.11) and maternal psychological adjustment, in terms of distress (p = 0.91, d = 0.24) and symptom intensity (p = 0.06, d = 0.55), did not differ between the mild TBI and control groups
Ganesalingam, 2008	Q1 & Q3	Parents and children reported the presence or absence of 15 cognitive, somatic, and emotional symptoms during the previous week, as well as the frequency of each symptom	PCS-I, HBI	<2-weeks & 3-months post-injury	Family functioning, parental distress, family burden	FAD-GF, BSI, FBII	<2-weeks & 3-months post-injury	• There was no difference between the mild TBI without LOC group and OI group in parental distress (p = 0.71, d = 0.05) or family burden (p = 0.48, d = 0.10) • Mild TBI with LOC was associated with greater family burden at 3-months than OI (p = 0.04, d = 0.37), independent of premorbid family functioning • Higher PCS shortly after injury was related to higher ratings of family burden and distress at 3-months
Yumul, 2020	Q1 & Q2	Parents reported whether PCS were observed in the child and recorded any symptoms reported by the child or observed by the parent that were not on the checklist	RPQ, with items added to reflect PCS common in children	<2-weeks & 3-months post-injury	Parental stress	PSI-SF	3-months post-injury	• There was no difference in parental stress between the mild TBI and superficial head injury groups (p = 0.56, d = 0.09) • Parental stress had significant predictive utility in determining parents' report of $\geq$2 symptoms at 3-months post-injury (OR = 1.03, 95% CI [1.00, 1.07], p = 0.04)

Bernard, 2016	Q2	Post-injury PCS scores reflected a change from parents' retrospective rating of their child's premorbid PCS	RPQ, PSC, ACE	<72 hours, 1-week, 1-month, & 3-months post-injury	Parental stress	PSI-SF	Not reported	• Higher levels of premorbid parental stress were a statistically significant predictor of PCS (OR = 1.02, 95% CI [1.01, 1.04], $p = 0.01$)
Bernard, 2020	Q2	Post-injury PCS scores reflected a change from parents' retrospective rating of their child's premorbid PCS	PCSS	>8-months post-injury	Parental stress	PSI-SF	>8-months post-injury	• Parenting stress, which demonstrated predictive utility 3-months post-injury, was not a significant predictor of PCS at 8-months post-injury (OR = 1.03, 95% CI [0.99, 1.07], $p = 0.19$)
Ewing-Cobbs, 2018	Q2	The presence or absence of PCS was dichotomized based on the ICD-10 criterion of at least 1 symptom present in at least 3 of the following areas: cognitive, emotional, somatic, sleep and/or fatigue	Post-concussion Symptom Inventory-Parent	Pre-injury, 3-, 6-, & 12-months post-injury	Family functioning	FAD-GF	As soon as possible after injury	• Poorer family functioning predicted greater emotional and cognitive symptoms • After adjusting for pre-injury PCS, the odds of chronic PCS were higher for children with poorer family function (OR = 2.42, 95% CI [1.23, 4.74], $p = 0.01$)
McNally, 2013	Q2	Parents and children rated somatic, cognitive, affective, and behavioral symptoms on a 4-point scale ranging from "never" to "often"	PCS-I, HBI	1- to 2-weeks post-injury, 1-, 3-, & 12-months post-injury	Family functioning, family stressors and resources, parental psychological adjustment	FAD-GF, LSSRI, General Severity Index of BSI	1- to 2-weeks post-injury	• Family factors, particularly parent adjustment, consistently predicted parent-reported, but not child-reported, symptom counts across time ([post-acutely ($p < 0.05$, $\beta = 0.25$)], [1-month ($p < 0.05$, $\beta = 0.20$)], [12-months ($p < 0.05$, $\beta = 0.15$)]) • Parent adjustment also predicted parent-reported somatic ([post-acutely ($p < 0.05$, $\beta = 0.19$)], [1-month ($p < 0.05$, $\beta = 0.24$)], [12-months ($p < 0.05$, $\beta = 0.13$)]) and cognitive symptoms ([post-acutely ($p < 0.05$, $\beta = 0.19$)], [1-month ($p < 0.05$, $\beta = 0.13$)], [3-months ($p < 0.05$, $\beta = 0.12$)]), such that higher levels of

								parental distress predicted higher levels of symptoms
Yeates, 2012	Q2	PCS are defined as subjective somatic, cognitive, and emotional problems	PCS-I, HBI	<3-weeks, 1-month, 3-months, & 12-months post-injury	Family functioning, family stressors & resources	FAD-GF, LSSRI	<3-weeks post-injury	• PCS following mild TBI were more apparent among children from higher-functioning families (p = 0.002; d = 12.40) with greater resources (p = 0.001; d = 13.48)
Legarreta, 2018	Q2	PCS were defined as ≥3 symptoms present 6-weeks post-injury	PCSS	6-weeks post-injury	Family psychiatric history	Clinical interview by neuropsychologist & corroborated by adult family member	6-weeks post-injury	• Concussed high school athletes with a family psychiatric history were >2.5 times more likely to develop PCS than controls (OR = 2.52, 95% CI [1.20, 5.30], p = 0.03) • Those with a family history of anxiety (OR = 2.99, 95% CI [1.36. 6.49], p = 0.02) or bipolar disorder (OR = 2.74, 95% CI [1.14, 6.67], p = 0.04) were specifically at increased risk of PCS
Morgan, 2015	Q2	Participants with PCS were defined as those experiencing symptoms for greater than 3 months	Retrospective review of medical record	NA. PCS were retrospectively identified as acute-phase symptoms (0-24 hours) or subacute-phase symptoms (0-3 weeks)	Family psychiatric history	Retrospective review of medical record	NA	• Risk for development of PCS was higher in those with a family history of mood disorders (OR = 3.1, 95% CI [1.1, 8.5], p = 0.026)
Olsson, 2013	Q2	Persistent PCS were defined as symptoms lasting longer than 3 months	Derived from items on the CBCL that demonstrated face validity with post-	<6-weeks, 6- & 18-months post-injury	General mental health, including somatic, anxiety, depression,	GHQ	<6-weeks, 6- & 18-months post-injury	• Pre-injury parental depression predicted PCS at 6-months (p = 0.001, β = 0.513), but not at 18-months post-injury for children with uncomplicated mild TBI • Pre-injury parental anxiety did not predict PCS at 6-months but did predict

			concussion disorder symptoms outlined in the DSM-IV		and social dysfunction symptoms			PCS at 18-months post-injury ($p < 0.001$, β = 0.851) for children with uncomplicated mild TBI, such that higher parental anxiety was associated with more PCS • Higher pre-injury parental anxiety was associated with fewer PCS at 6-months ($p = 0.023$, β = -0.432), but did not predict PCS at 18-months for children with mild TBI (no imaging) • Pre-injury parental depression was not a significant predictor for children with mild TBI (no imaging)
Teel, 2022	Q2	Recovery was defined as the duration of in-clinic care (# of days between initial visit and clinic discharge) and time to clinical recovery (# of days between the injury and clinic discharge)	PCS-I	10-days post-injury	Parental stress, child-parent relationship	PSS, CPRS, clinical interview	10-days & 1-month post-injury	• Higher perceived parental stress, but not pre-existing anxiety, was related to longer recovery time (hazard ratio = 2.162, 95% CI [1.075, 4.348], $p = 0.03$) for the injured child • Based on a clinical interview, parents reported their stress was directly tied to their child's symptoms and overall functioning
Truss, 2020	Q2	Recovery was defined as the resolution of PCS within 4-weeks post-injury	PCS-I	1- to 4-days, 2-weeks, 1-month, & 3-months post-injury	Parental psychological distress	K10	2-weeks post-injury	• Greater acute parent psychological distress increased the odds of children experiencing severe and persistent PCS (OR = 1.24, 95% CI [1.08, 1.42], $p = 0.002$)
Zemek, 2013	Q2	A PCS case was defined as $\geq$3 symptoms at 1-month post-injury, compared to pre-concussion baseline, per ICD-10 definition	PCS-I	<48 hours, 3-days, 7-days, 2-weeks, 1-month, & 3-months post-injury	Parental anxiety	STAI-S	<48 hours, 2-weeks, 1-month, & 3-months post-injury	• Parental anxiety at acute presentation was not associated with children's prolonged symptoms at 1-month post-injury (OR = 1.12, 95% CI [0.71, 1.75], $p = 0.63$)

Lalonde, 2020	Q3	Parents reported whether PCS were present or absent in their child at any time after injury, based on the ICD-10 diagnostic criteria for post-concussion syndrome	PCS-I	6-months post-injury	Parent-child interactions	MRO	6-months post-injury	• Children who had a greater number of PCS demonstrated better parent-child interactions in both a snack-centered activity (p = 0.089, d = 0.43) and a toy-centered activity (p = 0.175, d = 0.37)

Note. PCS-I=Post-Concussive Symptom Interview; RPQ=Rivermead Post Concussion Symptoms Questionnaire; ED=Emergency Department; FAD-GF=General Functioning Scale of the McMaster Family Assessment Device; BSI=Brief Symptom Inventory; PSC=Post-injury Symptom Checklist ACE=Acute Concussion Evaluation; PSI-SF=Parenting Stress Index-Short Form; ICD=International Classification of Diseases; PCSS= Post-concussion Symptom Scale; HBI=Health Behaviour Inventory; FBII=Family Burden of Injury Interview; LOC=Loss of consciousness; OI=Orthopedic injury; MRO=Mutually Responsive Orientation scale; LSSRI=Life Stressors and Social Resources Inventory; CBCL=Child Behaviour Checklist; DSM=Diagnostic and Statistical Manual of Mental Disorders; GHQ= General Health Questionnaire; PSS=Perceived Stress Scale; CPRS=Child-Parent Relationship Scale; K10=Kessler Psychological Distress Scale; STAI-S=State-Trait Anxiety Inventory-State Anxiety Scale.

Discussion

Most previous investigations of the association between parental and family functioning and child outcomes have focused on moderate to severe TBI. This review aimed to summarize the existing literature examining the relation between PCS and parental and family functioning on PCS after mild TBI. The studies included in this review varied in study design, sample sizes, participant demographics, comparison groups, time post-injury, and assessment measures. The domains of parental and family functioning that were assessed were also heterogenous. However, we purposely conducted a broad search of the literature using inclusive criteria to reflect the breadth of characteristics of the family environment that might be related to children's recovery after mild TBI.

Three studies addressed whether mild TBI is associated with greater levels of parental or family functioning than other injuries (Barlow et al., 2010; Ganesalingam et al., 2008; Yumul et al., 2020). Although any conclusions must be made cautiously due to the small number of studies examined and the heterogeneity in comparison groups, mild TBI may not be associated with differences in parental or family functioning, except perhaps in the case of more severe injuries, such as those accompanied by LOC. In other words, based on a small literature, mild TBI appears unlikely to result in greater parental distress or poorer family functioning than other types of injuries.

Twelve studies addressed whether pre-injury or acute parental and family functioning predict later PCS after mild TBI. Eleven of these studies reported that pre-injury or acute parental or family functioning predicted subsequent PCS and four studies reported that aspects of family functioning were not predictive of later PCS (Bernard et al., 2020; Olsson et al., 2013; Teel et al., 2022; Zemek et al., 2013). Parental and family functioning may have utility in predicting PCS; however, specific family characteristics, such as parental anxiety, may not be associated with subsequent PCS, particularly as time post-injury increases. Further research is needed to delineate the influence of specific parent and family characteristics on PCS after mild TBI.

Two studies addressed whether acute PCS predict later parental and family functioning after mild TBI (Ganesalingam et al., 2008; Lalonde et al., 2020) and reported mixed findings. The inclusion of only two relevant studies and their inconsistent findings highlights the paucity of research addressing the potential bidirectional nature of PCS and the family environment after mild TBI.

The finding that mild TBI may not be associated with differences in parental or family functioning compared to other injuries, except perhaps in the case of more severe injuries, is consistent with previous research suggesting that mild TBI is less likely to adversely affect the family compared to moderate or severe TBI (Rivara et al., 1994, 1996). Parents of children who sustain a mild TBI likely experience some distress at the time of injury, but they do not appear to experience a significant decline in parental and family functioning above and beyond parents of children who sustain other types of injuries. Previous research has determined that PCS typically resolve within three months (Barlow et al., 2010; Zemek et al., 2016) and children with mild TBI recover with limited long-term impairments (Babikian & Asarnow, 2009; Lloyd et al., 2014). Parents of children who experience persistent PCS (i.e., beyond 3-months post-injury) may experience ongoing or increased distress related to their child's recovery, so it is possible that PCS may be a better predictor of later parental and family functioning than injury type.

Pre-injury or acute parental and family functioning predicts subsequent PCS in children after mild TBI, depending on the specific parent or family characteristic studied. A family that is already functioning poorly may impede or delay a child's recovery through increased family stress, poor coping strategies, or inadequate support systems (e.g., ability to attend medical appointments and follow medical recommendations, ability to advocate for a temporary reduction in school-related burden for the child, etc.). However, Yeates et al. (2012) reported that parent-reported somatic symptoms were more pronounced in children with mild TBI relative to orthopedic injuries who were from higher functioning families and who had more resources. Higher functioning families with more resources may be more attentive to their child and aware of their symptoms after injury. Family functioning is a broad domain and different characteristics of the family environment may serve as either a protective or risk factor for subsequent PCS, or specific family characteristics may not be associated with PCS. For example, two studies reported that parental anxiety did not predict later PCS (Teel et al., 2022; Zemek et al., 2013). Olsson et al. (2013) reported mixed findings based on time post-injury and type of mild TBI (i.e., uncomplicated mild TBI or mild TBI for which imaging was not clinically warranted). In contrast, previous studies have suggested that anxiety modulates the prolongation of concussion symptoms in adults (Edmed & Sullivan, 2012; Wood, McCabe & Dawkins, 2011), that parental anxiety is associated with persistent headache in children (Emiroglu et al., 2004; Feldman et al., 2010), and that a family history of anxiety increases the likelihood of high school athletes being diagnosed with post-concussion syndrome (Legarreta et al., 2018; Morgan et al., 2015). Nonetheless, acute parental anxiety after mild TBI in children does not appear to provide a unique contribution to predicting subsequent PCS, in the same way that other parental and family factors may.

Examination of the relation between early PCS and subsequent parental and family functioning yielded mixed results. Ganesalingam et al. (2008) reported that levels of acute PCS predicted more parental distress and family burden at 3-months post-injury but differences in family burden for children with high compared to low levels of early PCS tended to decrease over time. A child experiencing PCS might disrupt a family's routine and create stress and worry about the impact of the injury, resulting in increased parental distress and family burden. This distress may be particularly prominent early after injury but likely decreases over time as the family adjusts to the injury and the child's symptoms begin to improve. In contrast, Lalonde et al. (2020) found that children with more PCS demonstrated better parent-child interactions. Parents who perceive their children as being more symptomatic may become more responsive and willing to adapt to their child's needs, resulting in more harmonious parent-child interactions (Lalonde et al., 2020), in line with Yeates et al.'s (2012) findings reported above. Preliminary evidence suggests PCS may predict subsequent parental and family functioning, although higher levels of PCS may act as either a protective or risk factor for later family functioning. The small number and heterogeneity of the studies examined limit any conclusions regarding the nature of the relation between PCS and parental and family functioning. Again, more research is needed to provide a more comprehensive understanding of the association of early PCS with later parental and family functioning, as well as the potential bidirectional relation between them.

Limitations of the Available Literature

This review is limited by the paucity of studies investigating each question of interest and the heterogeneity among studies. The included studies varied in study design, sample size, participant demographics, and comparison groups. Predictor and outcome measures varied widely and were administered at varying times post-injury. Although this heterogeneity reflects the range of ways in which parental and family functioning and PCS can be assessed, it also limits the generalizability of each study's findings and the ability to compare findings across studies.

Another limitation involves the retrospective recall of data. Pre-injury family functioning was always rated retrospectively by parents, often at the time of their child's injury. Retrospective ratings may be subject to recall biases, particularly during a stressful time, such as an ED or concussion clinic visit. Additionally, most measures were completed by parents, who may have provided different ratings than their children would have on similar measures (e.g., children's pre-injury symptoms).

The included studies also varied in assessment time points. Most studies measured PCS and family functioning retrospectively or from the acute period after injury up to at least 3-months post-injury, however, several studies completed assessments at or beyond 8-months post-injury and several studies did not report the exact timing of their assessments (see Table 2 for details). Although PCS typically resolve within three months (Barlow et al., 2010; Zemek et al., 2016), some children will experience symptoms that persist beyond that time, so it is important to assess PCS beyond 3-months post-injury to distinguish between children who recovery fully and those who may be at risk for persisting symptoms. In addition, parental and family functioning both contribute to and are affected by children's recovery after TBI (Beauchamp et al., 2021; Raj et al., 2014; Taylor et al., 2001). Parents of children with persisting symptoms (i.e., beyond 3-months post-injury) may experience ongoing or increased distress related to their child's recovery, but longer and more consistent follow-up of parental/family functioning would be required to better understand this relationship and how it changes over time. Future investigations would benefit from administering measures at ample intervals (e.g., acutely, and at least until 12-months post-injury) to help advance our understanding of the critical times for post-injury assessment and intervention of PCS and parental/family functioning.

Most studies also did not include a comparison group. Of the studies with comparison groups, only one study recruited participants with orthopedic injuries and investigated parental or family functioning as a function of injury type (Ganesalingam et al., 2008). Children with orthopedic injuries are an appropriate comparison group due to their similarities to children with mild TBI in terms of demographic and risk factors that predispose them to injury, and because they help to control for the general effects of trauma on symptom reporting and the non-specific nature of PCS (Ware et al., 2020; Yeates et al., 2017). In contrast, using a comparison group of superficial head injuries (Yumul et al., 2020) could increase the likelihood that participants who sustained a mild TBI and consequent PCS are inappropriately included in the control group, hampering the identification of true differences between the groups.

Finally, the included studies used different definitions of concussion/mild TBI, limiting the generalizability of the findings. Most studies classified mild TBI as an injury resulting in a Glasgow Coma Scale score of 13 to 15 at ED admission, loss of consciousness or altered mental state, absence of focal neurological deficits, and posttraumatic amnesia lasting less than 24 hours. However, several studies recruited participants solely based on the confirmation of a diagnosis of concussion by an athletic trainer or physician (Legarreta et al., 2018; Morgan et al., 2015), while other studies included participants based on the presence of PCS after a direct or indirect blow to the head (Truss et al., 2020; Zemek et al., 2013). Nevertheless, of the studies that used retrospective data to diagnose concussion/mild TBI, most used information in the form of medical records to confirm a documented history of mild TBI, increasing the likelihood that only participants who actually sustained a mild TBI were included for review.

Conclusion

This scoping review highlights the need for further prospective, longitudinal studies with appropriate comparison groups that utilize comprehensive, standardized assessment of parental and family functioning to provide more definitive findings and a better understanding of the relation between parental and family functioning and PCS after mild TBI. Overall, the available evidence suggests that parental and family functioning has an important, and perhaps bidirectional, association with PCS after pediatric mild TBI. Recognizing the importance of parental and family functioning in relation to PCS after mild TBI will help inform clinical practice guidelines for the assessment and management of children at risk of poor recovery after mild TBI.

Chapter 3: Study 2

Parental and Family Functioning as Predictors of Longitudinal Trajectories of Post-concussive Symptoms Following Pediatric Mild Traumatic Brain Injury

Abstract

The family environment plays an important role in children's recovery from traumatic brain injury (TBI); however, parental and family factors have not been examined in depth in pediatric mild TBI, so their importance remains unclear. Additionally, existing research on post-concussive symptoms (PCS) typically employs conventional statistical analyses that assume that children with mild TBI are a homogenous group. However, children may display distinct patterns of PCS after mild TBI, particularly when studied across time. A statistical technique called group-based multi-trajectory modeling can identify latent clusters of individuals following similar trajectories across multiple indicators of an outcome. The objective of this study was to identify different trajectories of PCS after mild TBI in children and to examine their association with parental and family functioning, compared to children with orthopedic injuries (OI). Participants were children/adolescents aged 8- to 16-years-old with either mild TBI or OI. Children were recruited during Emergency Department (ED) visits within 48-hours post-injury at five hospitals across Canada. Injury information was collected in the ED and parental and family functioning and PCS were measured at approximately 7-days, 3-months, and 6-months post-injury. PCS ratings were also obtained electronically, weekly to 3-months and biweekly thereafter. PCS were measured using the Health and Behaviour Inventory. Parental and family functioning were assessed using validated measures of family functioning, parental adjustment, perceived social support from parents, and parental responses to children's symptoms. Group-based multi-trajectory modeling was used to classify individual children into distinct trajectories of child- and parent-reported cognitive and somatic PCS over time and to examine predictors of those trajectories. Several demographic factors, such as injury type, sex, retrospective PCS, and 5P clinical risk score, were identified as significant predictors of PCS trajectory membership.

Several parental and family factors were also identified as significant predictors of trajectory membership after mild TBI, including parental adjustment, protectiveness, and social support. Identification of different symptom trajectories and the influence of parental and family functioning as predictors of those trajectories provides guidance for clinicians in developing family-based treatments and enabling the targeting of those treatments to children at risk for poor recovery.

Introduction

Millions of children sustain a TBI every year, with most injuries being mild in severity (Bryan et al., 2016; CDC, 2019). Both injury-related (e.g., injury severity, mechanism of injury) and noninjury-related factors (e.g., age, sex, coping strategies) can influence recovery from TBI, and research suggests that noninjury-related factors may explain relatively more variability in mild TBI outcomes than injury-related factors (Luis et al., 2003; Ponsford et al., 1999). Parents and the family environment play a particularly important role in children's recovery from TBI. General family functioning appears to moderate outcomes after TBI, such that more favourable family environments are associated with more positive outcomes, including better behavioural adjustment (Taylor et al., 2002), academic performance (Taylor et al., 2002), and social functioning (Ryan et al., 2016; Yeates et al., 2010). Parental psychological adjustment has also been linked to outcomes after TBI, such that poor parental functioning is associated with more child behavioural problems (Raj et al., 2014; Raj et al., 2014; Taylor et al., 2001) and lower adaptive functioning (Micklewright et al., 2012). Research suggests that other family factors, such as social support and parents' responses to their children's symptoms, may also be related to outcomes after TBI, but have not yet been widely investigated.

Although research has been conducted on the influence of parental and family factors on pediatric TBI outcomes, this has been primarily in the context of moderate and severe TBI (Raj et al., 2014; Ryan et al., 2016; Taylor et al., 2001; Taylor et al., 2002; Yeates et al., 2010). The prevalence of mild TBI far outweighs that of more severe TBI, so a better understanding of the impact of parents and the family environment on mild TBI recovery is imperative. Parental and family factors have not been examined in detail in pediatric mild TBI, so the importance of parenting and the family environment to mild TBI recovery remains unclear. Previous studies of mild TBI are limited by a focus on youth recovering from sport-related concussion sustained during high school sporting activities. Prospective, longitudinal investigations of younger children and in non-sport-related settings are lacking. Unfavourable family environments may exacerbate the adverse effects of mild TBI on all children, regardless of age and injury setting; therefore, the role of the family environment warrants further investigation and should be a central consideration in the study of pediatric TBI.

Much of the existing research on PCS in children with mild TBI employs conventional statistical analyses that assume that these children are a homogenous group who follow a similar recovery trajectory. Most systematic reviews report few, if any, long-term impairments after pediatric mild TBI (Babikain & Asarnow, 2009; Lloyd et al., 2014). However, the assumption that children with mild TBI are a homogenous group is likely incorrect, as individual children may display distinct patterns of PCS after mild TBI, particularly when studied across time. Yeates and colleagues (2009) reported distinct post-injury trajectories of PCS in children after mild TBI compared to orthopedic injuries (OI). Children were 8- to 15-years old at the time of injury and were assessed for PCS over the span of 12-months post-injury. The researchers used finite mixture modeling to identify four longitudinal PCS trajectories: no PCS, moderate persistent PCS, high acute/resolved PCS, and high acute/persistent PCS. The distribution of trajectories differed by injury type, such that children with mild TBI were more likely to follow the two trajectories with high acute levels of PCS than children with OI. This pattern was particularly likely for children with mild TBI who displayed an acute clinical presentation reflecting a more severe injury (Yeates et al., 2009).

Recovery from mild TBI is a complex process that involves the interplay of individual, injury, and environmental factors. Identifying and monitoring multiple indictors of recovery over time is crucial for a complete understanding of the recovery process. A statistical technique called group-based multi-trajectory modeling can identify latent clusters of individuals following similar trajectories across multiple indicators of an outcome, effectively mapping the developmental course of symptoms (Nagin & Odgers, 2010; Nagin et al., 2018). Group-based multi-trajectory modeling aims to identify distinct patterns within longitudinal data, not to identify the "true" number of distinct trajectory groups (Nagin et al., 2018). Thus, this technique conceptualizes latent trajectory groups as clusters of individuals who follow a similar trajectory, not as distinctly different groups of individuals (Nagin et al., 2018). Group-based multi-trajectory modeling has been applied to examine long-term functional recovery from severe TBI (Hammond et al., 2019), but has not yet been used to examine children's recovery from mild TBI. This statistical approach should provide a more complete, accurate, and clinically relevant characterization of individual outcomes after mild TBI.

The objective of this study was to identify different trajectories of child- and parent-reported PCS after mild TBI in 8- to 16-year-old children and to examine their association with parental and family functioning across the first 6-months post-injury, as compared to children with OI. Aim 1 of the current study is to identify latent trajectories of somatic and cognitive PCS and determine whether they differ as a function of injury type (mild TBI versus OI). Hypothesis 1 is that children with mild TBI will demonstrate trajectories reflecting higher levels of child- and parent-reported cognitive and somatic PCS compared to children with OI. PCS are not specific to head injuries, but children with injuries to regions of the body other than the head are unlikely to exhibit the same level of PCS as children with mild TBI (Meares et al., 2008). Aim 2 is to examine whether latent PCS trajectories are predicted by premorbid parental and family functioning. Hypothesis 2 is that better parental and family functioning will be associated with

PCS trajectories showing lower acute levels of PCS and more rapid recovery for both children with mild TBI and OI. More specifically, we predict that poorer premorbid parental and family functioning will predict trajectories with higher acute levels of child- and parent-reported PCS and slower recovery for children with mild TBI.

Methods

Study Design and Procedure

This study drew on data from a larger parent study, the Advancing Concussion Assessment in Pediatrics study (A-CAP; Yeates et al., 2017). A-CAP involved a prospective, concurrent cohort design with longitudinal follow-up. Participants were children and adolescents with either mild TBI or OI not involving the head. Children were recruited during ED visits within 48-hours post-injury at five hospital sites across Canada, all members of the Pediatric Emergency Research Canada network (PERC; Pediatric Emergency Research Canada, 2019). Injury information was collected in the ED and parental and family functioning and PCS were measured at approximately 7-days, 3-months, and 6-months post-injury. At the 7-day timepoint, parents also rated their children's pre-injury cognitive and somatic symptoms during the week prior to their injury. PCS ratings were also obtained electronically, weekly to 3-months and biweekly thereafter. In total, children and parents completed three face-to-face and 18 remote PCS ratings. PCS were measured using the Health and Behaviour Inventory, a validated rating scale (HBI; Ayr et al., 2009). Parental and family functioning were assessed using validated measures of family functioning (McMaster Family Assessment Device [FAD]; Byles et al., 1988), parental adjustment (Kessler Psychological Distress Scale [K6]; Kessler et al., 2003), perceived social support from parents (Child and Adolescent Social Support Scale [CASSS]; Malecki & Demaray, 2002), and parental responses to children's symptoms (Adult Responses to

Children's Symptoms [ARCS]; Noel et al., 2015). Children and parents completed the HBI, children completed the CASSS, and parents completed the FAD, K6, and ARCS.

The objective of A-CAP was to assess a broad pool of neurobiological and psychosocial markers to examine associations with post-injury outcomes in children with either mild TBI or OI, with the goal of improving the diagnosis and prognostication of outcomes of pediatric mild TBI (Yeates et al., 2017). The A-CAP study was approved by the University of Calgary Conjoint Health Research Ethics Board (REB15-2296) and the study was conducted in compliance with internal review board standards for ethical clinical pediatric research at all participating institutions.

Participants

Participants were children/adolescents aged 8.00-16.99 years at the time of injury, with mild TBI or OI. The exclusion of younger children helped to ensure that participants were capable of self-report and the exclusion of older adolescents was in part for practical reasons, because they appear relatively infrequently in the EDs at the participating sites, but also reduced developmental heterogeneity within the sample. Children with OI were selected as the comparison group due to their similarities to children with mild TBI in terms of demographic and risk factors that predispose them to injury, and to help control for the general effects of trauma on symptom reporting and the non-specific nature of PCS (Ware et al., 2020; Yeates et al., 2017).

Children with mild TBI were eligible for the study if they sustained a blunt head trauma resulting in at least one of the following three criteria, consistent with the WHO definition of mild TBI (Carroll et al., 2004): (1) an observed loss of consciousness, (2) a Glasgow Coma Scale (GCS) score of 13 or 14 or (3) at least one acute sign or symptom of concussion/mild TBI as noted by ED medical personnel on a standard case report form (i.e., post-traumatic amnesia, focal neurological deficits, skull fracture, post-traumatic seizure, vomiting, headache, dizziness, other mental status changes). Children with OI were included in the study if they sustained upper or lower extremity fractures, sprains, or strains due to blunt force trauma, associated with Abbreviated Injury Scale (AIS; American Association for Automotive Medicine, 1990; a measure of injury severity) scores of four or less. Children in both groups must have presented to one of the five EDs within 48-hours of injury. Children transferred from an outside hospital were still eligible if study enrolment occurred within 48-hours of injury.

Children with mild TBI were excluded if they demonstrated delayed neurological deterioration (i.e., any GSC <13) or required neurosurgical intervention. Children whose injuries were accompanied by a loss of consciousness for more than 30 minutes or post-traumatic amnesia greater than 24 hours were excluded, as were those with any associated injury with an AIS score greater than four, to avoid associated injuries worse than those in the OI group, although children with mild TBI may have had associated injuries of lesser severity. Exclusion criteria for children with OI included any evidence of head trauma or symptoms of concussion/mild TBI at the time of recruitment, as well as any injury requiring surgical intervention or procedural sedation, including closed reductions. Children were not excluded from either group if they were administered analgesic medication, including narcotics, solely for pain management. Both injury groups were subject to multiple additional exclusion criteria: (1) hypoxia, hypotension or shock during or following the injury (if known at the time of recruitment); (2) non-English-speaking child or parents (non-English and non-French-speaking in Quebec or Ottawa); (3) previous TBI requiring overnight hospitalisation, by parent report; (4) previous concussion/mild TBI within the past three months, by parent report, to exclude children still in the acute phase of recovery; (5) previous severe neurological or neurodevelopmental disorder such as epilepsy, intellectual disability, or autism, by parent report (history of attention deficit hyperactivity disorder, learning disability or Tourette's syndrome was not an exclusion); (6) hospitalisation in the previous year for psychiatric disorder, by parent report; (7) administration of sedative medication (propofol, ketamine, nitrous oxide, midazolam, benzodiazepines) prior to ED data collection (fentanyl was not an exclusion if used for pain management only); (8) obvious alcohol or drug ingestion associated with injury; (9) injury related to abuse or assault; and (10) legal guardian not present or child in foster care (Yeates et al., 2017).

Recruitment

Recruitment occurred during ED visits at five sites in the PERC network (Bialy et al., 2018): Alberta Children's Hospital (Calgary, AB), Stollery Children's Hospital (Edmonton, AB), British Columbia Children's Hospital (Vancouver, BC), Children's Hospital of Eastern Ontario (Ottawa, ON), and Ste Justine Hospital (Montreal, QC). The inclusion of five sites across Canada ensured recruitment of a sufficiently large and representative sample of children. Recruitment was completed by dedicated staff that completed screening of all potentially eligible children who presented to the ED during study enrolment hours (approximately 08:00-23:00, 7 days a week, depending on available staffing). Eligible and willing parents, along with adolescents capable of consenting on their own behalf, were asked for written informed consent; assent was requested from children who were not capable of providing informed consent themselves. Physicians were notified of enrolment and asked to complete a standardised case report form regarding the participant's medical presentation. Recruitment began in September 2016 and concluded in December 2018, with another 6 months needed to complete all follow-up visits; thus, the study concluded by mid-2019 (Yeates et al., 2017).

A total of 3051 (mild TBI *n* = 1408; OI *n* = 1643) children were eligible for participation in A-CAP. Of the eligible children with mild TBI, 633 (45%) consented to participate; of the eligible children with OI, 334 (20%) consented. Of these 967 children who were recruited in the ED, 826 (85% of consented) completed the post-acute assessment (548 [87% of consented] with mild TBI, 278 [83% of consented] with OI), 722 (74%) completed the 3-month assessment (475 [75%] with mild TBI, 244 [73%] with OI), and 691 (72%) completed the 6-month assessment (454 [72%] with mild TBI, 238 [71%] with OI). Of the total 967 participants, 640 completed all three assessments (422 [67%] with mild TBI, 218 [65%] with OI). Retention rates were comparable across groups and among the five recruitment sites (see Table 4 for participant consent and retention rates).

Table 4

Participant Consent and Retention Rates

Number of Participants Consented

	Consented	Not Consented
Mild TBI	633	775
OI	334	1307
Unknown	-	2
Total	967	2084

Participants at the Post-acute Assessment

	Frequency	Percent
Missed	90	9.31%
Complete	827	85.52%
Withdrew	50	5.17%
Total	967	100%

Participants at the 3-month Assessment

	Frequency	Percent
Missed	166	17.17%
Complete	722	74.66%
Withdrew	29	3%
Withdrew Previously	50	5.17%
Total	967	100%

Participants at the 6-month Assessment

	Frequency	Percent
Missed	176	18.2%
Complete	691	71.46%
Withdrew	21	2.17%
Withdrew Previously	79	8.17%
Total	967	100%

Participant Retention Rates Across Recruitment Sites

	Post-acute	3-months	6-months
Vancouver			
Mild TBI	87.02%	70.99%	71.76%
OI	85.32%	72.48%	66.97%
Calgary			
Mild TBI	86.67%	81.33%	76.67%
OI	80.26%	69.74%	72.37%
Edmonton			
Mild TBI	90%	78.33%	78.33%
OI	84.38%	79.69%	76.56%
Montreal			
Mild TBI	84.51%	77.46%	64.79%
OI	79.31%	79.31%	75.86%
Ottawa			
Mild TBI	85.09%	70.19%	64.6%
OI	83.93%	69.94%	69.64%
Total			
Mild TBI	86.73%	75.36%	71.56%
OI	83.23%	73.35%	71.26%

Data Collection

At the time of recruitment, research staff members collected information regarding the injury and the child's acute clinical presentation. After initial data collection was completed in the ED, the local research coordinator contacted families to schedule the initial assessment, which occurred on average 8.44 days post-injury (*SD* = 3.14); 42% occurred within 7-days after injury and 97% occurred within 14-days after injury (maximum = 26 days). Children and their parents then completed assessments again at 3- and 6-months post-injury.

The post-acute assessment included measures of neurobiological and psychosocial variables, PCS, and functional outcomes, as well as potential covariates, confounders, and moderators (Yeates et al., 2017). Subsequent follow-up assessments at 3- and 6-months post-injury included measures similar to those completed at the post-acute assessment (e.g., symptoms and post-injury functional outcomes). At all visits, researchers also collected demographic information, as well as information about subsequent injuries and any interventions and treatments received.

The post-acute assessment lasted approximately two hours, and the 3- and 6-month assessments lasted approximately 90 minutes. Parents and children were reimbursed with gift certificates for their time during each visit. Multiple methods were used to track participants and limit attrition (Yeates et al., 2017).

Measures

McMaster Family Assessment Device

Family functioning was assessed with the General Functioning subscale from the McMaster Family Assessment Device (FAD; Byles et al., 1988; see Appendix B). The FAD is a 60-item scale that measures family functioning. Respondents indicate the degree to which they agree or disagree with statements about families by rating each item on a 4-point Likert scale (1 = strongly agree, 2 = agree, 3 = disagree, 4 = strongly disagree). Subscale scores are computed by summing the ratings for each of the seven subscales, with higher scores reflecting worse family functioning. The General Functioning subscale consists of 12 items that measure overall family health/pathology. Six items describe healthy family functioning, and the other six items describe unhealthy functioning. Parents completed the General Functioning subscale by responding to statements, such as "In times of crisis we can turn to each other for support." Retrospective family functioning was assessed at the post-acute visit.

The FAD is a reliable indicator of retrospective family functioning, with an internal consistency (Cronbach's alpha) of .87 in the data analysed for the current study. Reliability and validity of the FAD (Kabacoff et al., 1990; Miller et al., 1985), as well as the General Functioning subscale (Byles et al., 1988), has been established in previous research. The FAD discriminates between nonclinical families and psychiatric families, such that families rated by clinicians as unhealthy had significantly higher FAD scores compared to families rated as healthy. Evidence of concurrent validity has also been established: the correlation between scores on the FAD and the Family Unit Inventory, a well-known self-report family assessment measure, were in the predicted direction (greater than .50; Miller et al., 1985). The General Functioning subscale has demonstrated good internal consistency (Cronbach's alpha ranging from .83 to .86 across studies; Byles et al., 1998; Kabacoff et al., 1990) and test-retest reliability (.71 at an interval of one week; Miller et al., 1985) in previous research.

Kessler Psychological Distress Scale

Parental psychological adjustment was assessed with the Kessler Psychological Distress Scale (K6; Kessler et al., 2003; see Appendix C). The K6 is a 6-item scale that was developed as a brief screen for serious mental illness based on the Diagnostic and Statistical Manual of Mental Disorders 4th edition (DSM-IV). The K6 assesses non-specific distress and discriminates between cases of mental illness and non-cases. Parents rated their retrospective psychological adjustment at the post-acute visit by indicating the type and frequency of distress experienced in the previous 30 days.

The K6 is a reliable indicator of retrospective parental psychological adjustment, with an internal consistency (Cronbach's alpha) of .79 in the data analysed for the current study. The K6 was developed in collaboration with the United States government's National Center for Health Statistics for use in the United States National Health Interview Survey and the National Household Survey on Drug Abuse (Kessler et al., 2010). Previous studies have established the K6 as a reliable and valid measure of psychological distress in adults throughout the world (Drapeau et al., 2010; Furukawa et al., 2003, 2008; Kessler et al., 2010; Mitchell & Beals, 2011; Prochaska et al., 2012). The K6 has demonstrated very good concordance with blinded clinical diagnoses of serious mental illness in the general population (Kessler et al., 2002, 2003, 2010).

Adult Responses to Children's Symptoms

Parental responses to children's symptoms were assessed using the Adult Responses to Children's Symptoms (ARCS; Noel et al., 2015; see Appendix D). The ARCS is a 26-item scale that assesses parental response styles in response to symptom complaints in children 7-18 years of age. Parents are asked to indicate how often they engage in a variety of behaviours by rating each item on a 5-point Likert scale (1 = never, 5 = always). ARCS consists of four subscales for children (ages 7-11), five subscales for adolescents (ages 12-18), and four subscales for children and adolescents combined (ages 7-18): protect, minimize, monitor, and distract (and solicitousness for adolescents). The four combined subscales were used to assess parents' responses in the current study. Parental responses to children's symptoms were assessed at the post-acute visit.

The ARCS is an acceptable indicator of parental responses to children's and adolescent's symptoms, with an internal consistency (Cronbach's alpha) of .85 for the Protect subscale, .78 for the Monitor subscale, .55 for the Minimize subscale, and .45 for the Distract subscale in the data analysed for the current study. Previous research has established the ARCS as a valid measure for use with children and adolescents with a variety of chronic pain complaints (Claar et al., 2010; Noel et al., 2015); however, the Protect subscale has received the most research attention due to the poorer internal consistency of the other subscales (Noel et al. 2016). The subscale scores are predictive of parental emotional functioning and psychological flexibility, as well as children's pain and functional disability (Noel et al., 2015). In particular, the Protect and Monitor subscales have been found to be sensitive to change (i.e., able to measure any degree of change) and responsive to change (i.e., able to assess change that is clinically significant) following intervention, reflecting good construct validity (Noel et al. 2016).

Child and Adolescent Social Support Scale

Social support was assessed using the Child and Adolescent Social Support Scale (CASSS; Malecki et al., 1999; see Appendix E). The CASSS is a 48-item scale that measures perceived social support of children and adolescents in Grades 3 to 12. Perceived support is evaluated from four sources: parents, teachers, classmates, and friends. Children respond to statements such as, "My parent(s) help me make decisions", by rating each item on a 6-point Likert scale (1 = never, 6 = always). Subscale scores are computed by summing the ratings for each of the four sources of support, and a total score is calculated by summing ratings for all four subscale scores. The Parent subscale, which consists of 12 items, was used to assess children's perceived social support from parents in the current study. Parental social support was assessed at the post-acute visit.

The CASSS is a reliable indicator of perceived social support from parents, with an internal consistency (Cronbach's alpha) of .92 for the Parent subscale in the data analysed for the current study. Previous research has established excellent internal consistency (Cronbach's alpha), with .97 for the Total score, .88-.96 for the Parent subscale, and .90-.97 across the other subscales (Malecki et al., 2014). Evidence of convergent validity has also been established: the correlation between scores on the CASSS and the Social Support Scale for Children (Harter, 1985), the only other widely used measure of social support, was .70 for the Total scale (Malecki & Demaray, 2002). The four-factor structure of the CASSS (parent, teacher, classmate, close friend) was originally confirmed by confirmatory factor analysis (Malecki & Demaray, 2002). More recently, confirmatory factor analysis supported a two-level hierarchical model representing both overarching global support at the higher level and the four sources of support at the lower level, providing support for the use of the total score and the subscale scores (Rueger et al., 2010).

Health and Behaviour Inventory

PCS ratings were obtained using the Health and Behaviour Inventory (HBI; Ayr et al., 2009; see Appendix F), a validated rating scale included in the National Institutes of Health Common Data Elements for TBI (McCauley et al., 2012) and incorporated in the Child Sport Concussion Assessment Tool (Child SCAT6; Davis et al., 2023). The HBI is comprised of 20 items that describe a variety of cognitive and somatic symptoms, yielding two subscales derived from factor analysis (Ayr et al., 2009; Zhang et al., 2022). The Cognitive PCS subscale includes 11 items, and the Somatic PCS subscale includes 9 items. Participants rated the frequency of occurrence of each item on a 4-point scale (0 = never, 1 = rarely, 2 = sometimes, 3 = often). Both children and their parents rated the child's PCS using the child and parent proxy forms of the

HBI. The child and parent forms are worded slightly differently due to the use of age-appropriate language and first- versus third-person perspective (Ayr et al., 2009). Children and their parents completed the HBI independently, outside of each other's presence. Child- and parent-reported HBI ratings were completed face-to-face at the post-acute, 3-month, and 6-month visits, as well as remotely on a weekly basis until 3-months post-injury and biweekly until 6-months post-injury. Parents also rated their child's pre-injury symptoms retrospectively during the post-acute assessment. Child and parent HBI ratings were analyzed jointly in the multi-trajectory models.

The HBI is a reliable indicator of child- and parent-reported PCS, with an internal consistency (Cronbach's alpha) of .99 for child cognitive ratings, .98 for child somatic ratings, .99 for parent cognitive ratings, and .97 for parent somatic ratings in the data analysed for the current study. Both the child and parent ratings of the HBI have also demonstrated good internal consistency across time in previous concussion research (Cronbach's alpha ranging from .86 to .91 for children's ratings and from .83 to .95 for parent ratings; McNally et al., 2013). The HBI has demonstrated validity in distinguishing mild TBI from other injuries, sensitivity to injury severity following TBI, and responsivity to treatment of youth with concussion (Fay et al., 2010; McCarty et al., 2021; Moran et al., 2011; Taylor et al., 2010).

Analyses

Group-based trajectory modeling is a statistical technique designed to identify a finite number of latent clusters of individuals following similar trajectories across an outcome of interest, whereas multi-trajectory modeling, an application of finite mixture modeling, can identify latent clusters of individuals following similar trajectories across multiple indicators of an outcome, effectively mapping the developmental course of symptoms (Nagin & Odgers, 2010; Nagin et al., 2018). Group-based multi-trajectory modeling is an extension of the univariate group-based trajectory modeling, designed to take full advantage of the multiple indicators of interest available in multivariate longitudinal data by analyzing them jointly rather than in sequence, as is typically done (Nagin et al., 2018).

In the current study, group-based multi-trajectory modeling was used to classify individual children in terms of their trajectories of child- and parent-reported cognitive and somatic PCS over time and to examine injury type, as well as parental and family functioning, as predictors of those trajectories. Demographic information, such as sex and race, was also examined to determine associations with PCS trajectories. To address Aim 1 of this study (identify latent trajectories of somatic and cognitive PCS and determine whether they differ as a function of injury type), group-based multi-trajectory modeling was conducted in the combined sample (both mild TBI and OI groups) across four outcomes: child-reported cognitive PCS, parent-reported cognitive PCS, child-reported somatic PCS, and parent-reported somatic PCS. To address Aim 2 of this study (examine whether latent PCS trajectories are predicted by premorbid parental and family functioning), group-based multi-trajectory modeling was conducted separately in the mild TBI and OI groups across all four outcomes and parental and family factors added as predictors of trajectory group membership. Group-based multi-trajectory modeling was conducted using the Traj plugin for Stata Version 18.0 (Jones & Nagin, 2013).

Model Building

Group-based multi-trajectory model building is an iterative process, and all models are estimated by maximum likelihood. The following steps recommended by Arrandale et al. (2006), Loughran and Nagin (2023), and Nagin (2005) were followed. The first step in building a group-based trajectory model is to determine the optimal number of latent trajectory subgroups. The expected number of groups is specified based on a descriptive analysis of the raw data and knowledge of the field. In the case of multi-trajectory modeling, which involve multiple outcomes, the number of subgroups for each trajectory model are first estimated for each of the outcomes separately. The objective is not to identify an optimal model for each outcome separately but instead to understand the distinctive features of the data and the types of distinctive trajectories that will be important to have represented in the final multi-trajectory model (Loughran & Nagin, 2023). The expected number of groups can also be specified by using the -2 log likelihood (-2LL) difference test and visually inspecting the model plots to examine differences between models sequentially. The model with the optimal number of trajectory groups maximises the Bayesian Information Criterion (BIC) and captures distinctive features of the data (Nagin, 2005). The model building process involves first testing a one-group model, and then gradually increasing the number of latent subgroups (Andruff et al., 2009; Loughran & Nagin, 2023). Models for up to six groups were estimated for each outcome.

Next, the optimal shape of the curve for each trajectory group is determined by identifying the highest order statistically significant polynomial term. The model building process typically involves a single quadratic trajectory model initially (Andruff et al., 2009). According to recommendations, if the single quadratic trajectory model is significant, a quadratic model with two trajectory subgroups should be analyzed. If that model is significant, the number of trajectories is increased, and the process is repeated until the model with the best fit is identified. If the initial single quadratic trajectory model is not significant, a linear trajectory model should be analyzed. Non-significance indicates that a polynomial term does not accurately describe the shape of a trajectory group (Loughran & Nagin, 2023; Nagin, 2005).

Lastly, the final model is selected and interpreted. For each individual, the group-based multi-trajectory model determines the probability of belonging to each trajectory subgroup, known as the posterior group probability (Loughran & Nagin, 2023). Individuals are assigned to the trajectory subgroup for which they have the highest posterior group probability (Lore et al., 2020). In addition to the BIC comparison, the proportion of the sample in each trajectory subgroup (more than 5% is recommended), the average posterior group probability (greater than or equal to 0.7 for each subgroup is recommended), and parsimony is taken into consideration when identifying the model with the best fit (Lore et al., 2020; Nagin, 2005). The Guidelines for Reporting on Latent Trajectory Studies (GRoLTS; van de Schoot et al., 2017) checklist was used as a guide to structure the reporting of the group-based multi-trajectory model results.

Results

Missing Data Analysis

Participants with all predictors and covariates, as well as at least one PCS assessment and who were not only seen in the ED, were included in the final sample. The final sample for this analysis included 767 children (mild TBI n = 506, OI n = 261). Little's Missing Completely at Random (MCAR) test was performed in Stata Version 18.0 (Jones & Nagin, 2013), with an expectation maximization technique, to examine missingness of child- and parent-report HBI ratings. The Little's test resulted in χ^2 (29,018) = 31,909.10, $p < .001$, indicating that the data in the final sample are not missing completely at random, as expected because of increasing attrition over time. Overall, child-reported HBI ratings were not missing for any of the post-acute assessments; 12.9% of the HBI ratings were missing for the 3-month assessments (13.2% in mild TBI and 12.3% in OI); and 16.0% of the HBI ratings were missing for the 6-month assessments (16.2% in mild TBI and 15.7% in OI). Parent-reported HBI ratings were not missing for any of the post-acute assessments; 13.2% of the HBI ratings were missing for the 3-month assessments (13.8% in mild TBI and 11.9% in OI); and 17.6% of the HBI ratings were missing for the 6-

month assessments (17.9% in mild TBI and 17.1% in OI). Of the participants included in the final sample, 213 (mild TBI *n* = 131, OI *n* = 82) completed all 21 child-reported HBI ratings (three face-to-face, and 18 remote) and 252 (mild TBI *n* = 151, OI *n* = 101) completed all 21 parent-reported HBI ratings; 554 participants (mild TBI *n* = 375, OI *n* = 179) completed at least one child-reported HBI rating and 515 (mild TBI *n* = 355, OI *n* = 160) completed at least one parent-reported HBI rating.

Participants excluded from the final sample did not differ from participants included in the final sample in age at injury, sex, injury group, parental education, material deprivation, concussion history, migraine history, family functioning, parental social support, parental psychological adjustment, or parent's reactions to children's symptom complaints. However, excluded participants did significantly differ from participants included in the final sample in race (χ^2 (5) = 11.34, $p = .045$, Cramer's V = .12 [low association]), mechanism of injury (χ^2 (8) = 36.89, $p < .001$, Cramer's V = .20 [low association]), headache history (χ^2 (2) = 10.11, $p = .006$, Cramer's V = .10 [low association]), and social deprivation (z = 2.186 , $p = .029$). See Table 5 for the distribution of race/ethnicity, mechanism of injury, headache history, and social deprivation for excluded participants compared to included participants.

Table 5

Group Differences Between Participants Included and Excluded from the Final Sample

	Included Participants	**Excluded Participants**
	***n* = 767**	***n* = 200**
Race		
% Asian *(n)*	8.2 (63)	17.9 (36)
% Black *(n)*	3.3 (25)	4.5 (9)
% Hispanic *(n)*	3.0 (23)	3.0 (6)
% Indigenous *(n)*	1.8 (14)	3.0 (6)
% Other/Multi-racial *(n)*	12.4 (95)	17.9 (36)
% White *(n)*	71.3 (547)	53.7 (108)
Pampalon Deprivation Index Percentile[1]		
Social Deprivation		
M (SD)	44.19 (27.02)	49.79 (29.14)
% History of headache *(n)*	76.1 (584)	70.3 (141)
Mechanism of Injury		
% Assault *(n)*	0.5 (4)	1.5 (3)
% Bicycle-related *(n)*	2.6 (20)	0.8 (1.6)
% Fall *(n)*	46.7 (358)	47.7 (95)
% Motor vehicle collision *(n)*	1.0 (8)	1.5 (3)
% Struck object *(n)*	28.0 (215)	22.0 (44)
% Struck person *(n)*	15.5 (119)	14.4 (29)
% Other *(n)*	3.3 (25)	1.5 (3)
% Not documented *(n)*	0.8 (6)	7.6 (15)
% Unknown *(n)*	1.6 (12)	3.0 (6)

Note. M = Mean; SD = standard deviation.
[1] An approximation of socioeconomic status based on material indicators that is normed nationally

Latent class modeling approaches, such as group-based multi-trajectory modeling, have the advantage of providing improved estimation if not all participants provide data at all time points (Lore et al., 2020). This is true for both data missing at random (Ray et al., 2018) and data not missing at random (Haviland et al., 2011). Participants with missing symptom data are still assigned to trajectory subgroups and can be used for model estimation. However, participants with missing data will generally have lower posterior group probabilities (the probability of belonging to each trajectory subgroup and the basis of subgroup assignment) than participants without missing data, which may increase the variability within each trajectory subgroup (Franklin et al., 2013).

Participant Characteristics

Participant characteristics of the final sample are outlined in Table 6. The final sample for this analysis included 767 children (mild TBI *n* = 506, OI *n* = 261). Participants were a mean age of 12.45 years old at the time of injury (*SD* = 2.42, Range = 8.00 to 16.96 years). Mean time from injury to follow-up visit was 8.34 days (*SD* = 3.06) and ranged from 1 to 26 days post-injury. Most of the sample experienced an injury sustained in a sport or recreational context (76.4%). No group differences were observed between the mild TBI and OI groups across demographic (e.g., age, sex, race, parental education, material deprivation index, social deprivation index) or pre-injury medical history (concussion history, headache history, migraine history) using t-tests and chi-squared tests, as appropriate. Group differences were observed between the injury groups for time since injury: the mild TBI group had significantly fewer days between the injury and acute follow-up visit compared to the OI group ($t(764) = -3.081$, $p = .002$, Cohen's $d = .24$ [small effect size]). Group differences were also observed between the injury groups for mechanism of injury ($\chi^2(8) = 56.92$, $p < .001$, Cramer's V = .27 [low association]). See Table 6 for the distribution of mechanism of injury, by injury group.

Table 6

Final Sample Characteristics by Injury Group

	Mild TBI	OI	Statistics		
	n = 506	*n* = 261	t/χ^2	*p*	d/V[1]
Age at Injury					
M (SD)	12.37 (2.51)	12.60 (2.22)	-1.27	.203	.10
Range	8.00-16.94	8.05-16.96			
Sex					
% Male *(n)*	59.7 (302)	54.4 (142)	1.98	.161	.05
Race					
% Asian *(n)*	8.5 (43)	7.7 (20)	5.06	.409	.08
% Black *(n)*	3.6 (18)	2.7 (7)			
% Hispanic *(n)*	2.2 (11)	4.6 (12)			
% Indigenous *(n)*	2.2 (11)	1.1 (3)			
% Other/Multi-racial *(n)*	12.1 (61)	13.0 (34)			
% White *(n)*	71.5 (362)	70.9 (185)			
Pampalon Deprivation Index Percentile[2]					
Social Deprivation					
M (SD)	43.48 (26.88)	45.55 (27.28)	-1.01	.317	.07
Range	1-100	1-100			
Material Deprivation					
M (SD)	34.10 (26.90)	34.09 (26.59)	.007	.994	.00
Range	1-100	1-98			
Parental Education[3]					
% ≤ High School *(n)*	15.2 (77)	15.3 (40)	1.24	.743	.04
% Trades/College Degree *(n)*	28.9 (146)	30.7 (80)			
% Bachelor's Degree *(n)*	38.3 (194)	34.5 (90)			
% Advanced Degree *(n)*	17.6 (89)	19.5 (51)			
Time Since Injury (days)					
M (SD)	8.10 (3.01)	8.81 (3.10)	-3.08*	.002	.24
Range	1-23	3-26			
% Previous concussion *(n)*	28.5 (144)	27.6 (72)	.067	.967	.01
% History of migraine *(n)*	6.1 (31)	6.9 (18)	.601	.741	.03
% History of headache *(n)*	75.7 (383)	77.0 (201)	.432	.806	.02
Mechanism of Injury					
% Assault *(n)*	0.6 (3)	0.4 (1)	56.92*	<.001	.27
% Bicycle-related *(n)*	1.6 (9)	4.2 (11)			
% Fall *(n)*	43.9 (222)	52.1 (136)			
% Motor vehicle collision *(n)*	1.6 (8)	0.0 (0)			
% Struck object *(n)*	31.8 (161)	20.7 (54)			
% Struck person *(n)*	18.2 (92)	10.3 (27)			
% Other *(n)*	1.2 (6)	7.3 (19)			
Injury Characteristics[4]					
% Sports/recreation *(n)*	81.8 (414)	-	-	-	-
% LOC *(n)*	15.2 (77)	-	-	-	-
% PTA *(n)*	19.4 (98)	-	-	-	-
% GCS <15 *(n)*	1.5 (8)	-	-	-	-

Note. TBI = traumatic brain injury; OI = orthopedic injury; M = Mean; SD = standard deviation; LOC = loss of consciousness; PTA = post-traumatic amnesia; GCS = Glasgow Coma Scale

[1] Cohen's *d;* Cramer's V

[2] An approximation of socioeconomic status based on material indicators that is normed nationally

[3] Primarily based on maternal education, paternal education if maternal not available

[4] Mild TBI group only

* Significant group difference ($p < .05$)

Table 7 provides an overview of child- and parent-reported PCS for the total sample and by injury group. Retrospective ratings of pre-injury symptoms reported by parents are also provided. Significant group differences were observed between the mild TBI and OI groups at all time points, except for child-reported cognitive symptoms and parent-reported somatic symptoms at 6-months post-injury, with the mild TBI group reporting more PCS than the OI group.

Table 7 also provides an overview of parental and family functioning reported by parents retrospectively or at the post-acute assessment. No group differences were observed between the mild TBI and OI groups in general family functioning, parental social support, or parental monitoring, minimizing or distraction in response to children's symptoms. However, the mild TBI group reported significantly worse parental psychological adjustment ($t(765) = 1.981$, $p = .048$, Cohen's $d = .15$ [small effect size]) and higher parental protectiveness in response to children's symptoms compared to the OI group ($t(765) = 6.163$, $p < .001$, Cohen's $d = .47$ [medium effect size]).

Table 7

Injury Group Differences in Parental/Family Functioning and PCS

	Mild TBI	OI	Statistics		
	n = 506	*n* = 261	t/χ^2	*p*	d/V[1]
Parental and Family Functioning					
FAD-GF Retrospective[2]					
M (SD)	18.90 (5.08)	18.70 (5.27)	0.50	.621	.04
Range	12-37	12-35			
K6 Retrospective[2]					
M (SD)	3.31 (3.31)	2.83 (3.08)	1.98*	.048	.15
Range	0-24	0-18			
CASSS Post-Acute[3]					
M (SD)	54.72 (10.13)	55.13 (10.48)	-5.18	.605	.04
Range	24-72	22-72			
ARCS Post-Acute[2]					
Protect					
M (SD)	1.78 (0.69)	1.45 (0.70)	6.15*	<.001	.47
Range	0.15-3.85	0.00-3.69			
Monitor					
M (SD)	3.34 (0.63)	3.25 (0.73)	1.71	.088	.14
Range	0.75-4.00	0.25-4.00			
Minimize					
M (SD)	0.66 (0.58)	0.71 (0.58)	-1.11	.269	.08
Range	0.00-2.75	0.00-2.50			
Distract					
M (SD)	2.18 (0.74)	2.28 (0.74)	-1.84	.067	.14
Range	0.00-4.00	0.00-4.00			
Post-concussive Symptoms					
HBI Cognitive Retrospective[2]					
M (SD)	8.94 (7.68)	7.20 (7.13)	3.13*	.002	.23
Range	0-31	0-29			
HBI Somatic Retrospective[2]					
M (SD)	2.73 (3.56)	2.11 (3.23)	2.46*	.014	.18
Range	0-26	0-25			
HBI Cognitive Post-Acute					
Child-report					
M (SD)	13.13 (8.25)	5.65 (5.74)	13.10*	<.001	1.00
Range	0-33	0-24			
Parent-report					
M (SD)	11.14 (8.14)	6.18 (6.73)	8.47*	<.001	.65
Range	0-33	0-31			
HBI Somatic Post-Acute					
Child-report					
M (SD)	9.79 (5.65)	2.90 (3.53)	17.98*	<.001	1.37
Range	0-27	0-21			
Parent-report					
M (SD)	6.85 (5.42)	1.51 (2.59)	15.04*	<.001	1.15
Range	0-27	0-20			
HBI Cognitive 3-Months					
Child-report					
M (SD)	7.51 (7.90)	5.79 (6.51)	2.83*	.005	.23
Range	0-31	0-28			

Parent-report					
M (SD)	7.90 (6.96)	6.13 (6.55)	3.23*	.001	.26
Range	0-30	0-29			
HBI Somatic 3-Months					
Child-report					
M (SD)	4.59 (5.05)	3.16 (4.11)	3.68*	<.001	.30
Range	0-25	0-24			
Parent-report					
M (SD)	3.12 (3.94)	1.98 (3.06)	3.83*	<.001	.31
Range	0-25	0-18			
HBI Cognitive 6-Months					
Child-report					
M (SD)	7.22 (7.71)	6.30 (6.73)	1.49	.136	.12
Range	0-31	0-26			
Parent-report					
M (SD)	7.62 (7.01)	6.09 (6.68)	2.65*	.008	.22
Range	0-31	0-28			
HBI Somatic 6-Months					
Child-report					
M (SD)	4.26 (4.89)	3.13 (3.90)	2.97*	.003	.25
Range	0-25	0-23			
Parent-report					
M (SD)	2.58 (3.48)	2.18 (3.18)	1.46	.146	.12
Range	0-20	0-18			

Note. TBI = traumatic brain injury; OI = orthopedic injury; M = Mean; SD = standard deviation; FAD-GF = McMaster Family Assessment Device (General Functioning subscale raw scores); K6 = Kessler Psychological Distress Scale (total raw score); CASSS = Child and Adolescent Social Support Scale (parent subscale raw score); ARCS = Adult Responses to Children's Symptoms (subscale raw scores); HBI = Health and Behaviour Inventory (subscale raw scores).

[1] Cohen's *d;* Cramer's V

[2] Only parent-reported

[3] Only child-reported

* Significant group difference ($p < .05$)

Modeling Cognitive and Somatic PCS Trajectories

Model 1: Child- and Parent-Reported Cognitive and Somatic PCS after mild TBI and OI

Modeling Outcomes Separately. Using the model building and selection procedure described earlier, each outcome was first modeled separately to identify distinctive feature of the data and the types of trajectories that it would be important to have represented in the final multi-trajectory model.

Child-Reported Cognitive PCS. A five-group trajectory model emerged as the preferred model for child-reported cognitive PCS. Model fit of the five-group model (BIC = -25793.17) significantly improved over the one-group model (BIC = -31325.93). Although model fit of a six-group model (BIC = -25564.71) improved slightly over the five-group model, the six-group model did not include additional trajectory groups that were substantively distinct from those captured by the five-group model.

Parent-Reported Cognitive PCS. A five-group trajectory model emerged as the preferred model for parent-reported cognitive PCS. Model fit of the five-group model (BIC = -27609.68) significantly improved over the one-group model (BIC = -34185.36). Although model fit of a six-group model (BIC = -27593.54) improved slightly over the five-group model, the six-group model did not include additional trajectory groups that were substantively distinct from those captured by the five-group model.

Child-Reported Somatic PCS. A five-group trajectory model emerged as the preferred model for child-reported somatic PCS. Model fit of the five-group model (BIC = -23349.26) significantly improved over the one-group model (BIC = -27524.16). Although model fit of a six-group model (BIC = -23126.54) improved slightly over the five-group model, the six-group model did not include additional trajectory groups that were substantively distinct from those captured by the five-group model.

Parent-Reported Somatic PCS. A five-group trajectory model emerged as the preferred model for parent-reported somatic PCS. Model fit of the five-group model (BIC = -21661.30) significantly improved over the one-group model (BIC = -25625.27). Although model fit of a six-group model (BIC = -21473.44) improved slightly over the five-group model, the six-group model did not include additional trajectory groups that were substantively distinct from those captured by the five-group model.

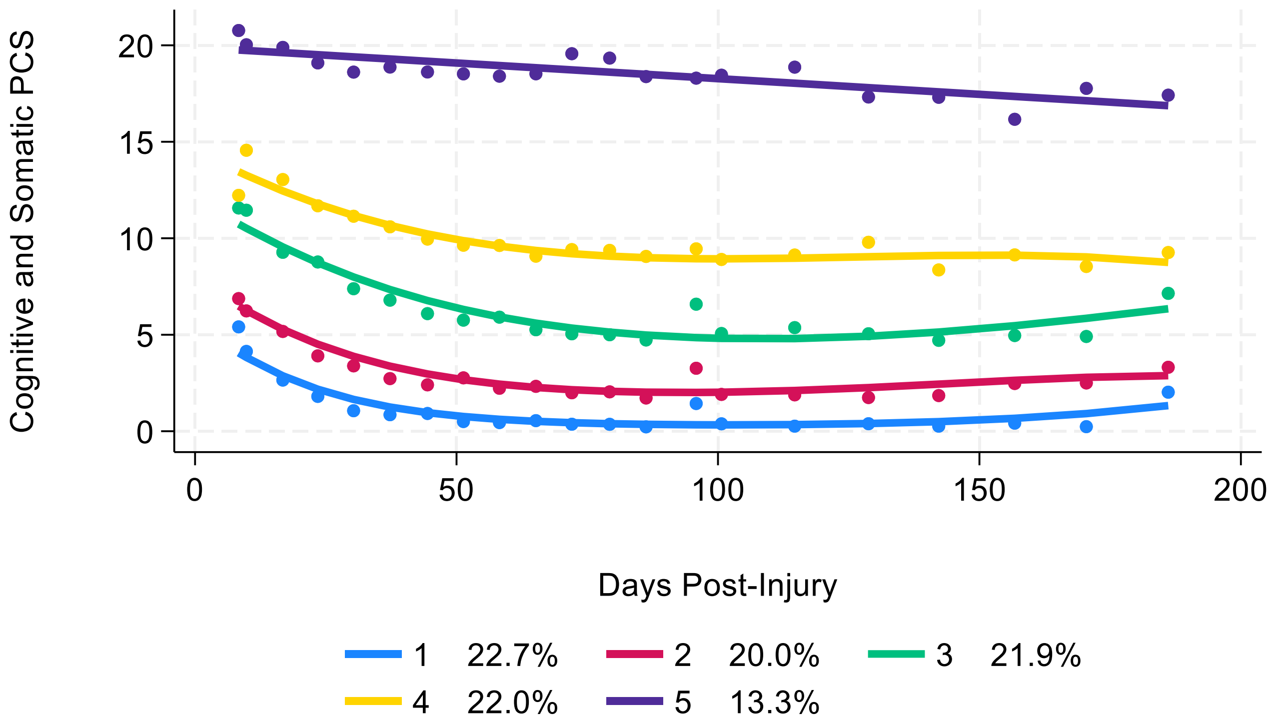
Unconditional Multi-Trajectory Model. A five-group trajectory model emerged as the preferred unconditional model for Model 1 (see Figure 2). Each trajectory group is defined by a trajectory for four outcomes: child-reported cognitive PCS, parent-reported cognitive PCS, child-reported somatic PCS, and parent-reported somatic PCS, assessed across the first 6-months post-injury (21 assessment timepoints in total). Cognitive and somatic PCS, which are measured on a psychometric scale, were modeled as following the censored normal distribution where the censored minimum was set at the scale minimum and the censored maximum was set at the scale maximum, respectively (Loughran & Nagin, 2023).

Based on the preferred models of the individual outcomes, a five-group model was first estimated. Model fit of the five-group model (BIC = -104562.73) improved over the four-group model (BIC = -105921.08). Although model fit of a six-group model (BIC = -103903.58) improved slightly over the five-group model, the six-group model did not include additional trajectory groups that were substantively distinct from those captured by the five-group model. The five-group model also captured the distinctive trajectories for each outcome that were revealed in the first stage of analysis, during which the number of subgroups for each model were estimated for each of the outcomes separately. In addition to the BIC comparison, the five-group model performed well on other tests of model adequacy laid out in Nagin (2005). The proportion of the sample in each trajectory subgroup was greater than the recommended 5%: 22.7% Group 1, 20.0% Group 2, 21.9% Group 3, 22.0% Group 4, and 13.3% Group 5. The average posterior group probability was greater than the recommended 0.70 for each subgroup: 0.98 Group 1, 0.97 Group 2, 0.97 Group 3, 0.96 Group 4, and 0.99 Group 5. In the interest of parsimony, the preferred multi-trajectory model included five trajectories.

Next, the optimal order and shape of each curve for each trajectory group was determined by identifying the highest order statistically significant polynomial term. Polynomials up to quintic terms were estimated for each outcome. 5 denotes a quintic term; 4 denotes a quartic term; 3 denotes a cubic term; 2 denotes a quadratic term; 1 denotes a linear term; and 0 denotes a constant term. The total number of terms within the parentheses reflects the total number of trajectory groups (i.e., five total terms within parentheses indicate there are five different trajectories). Each number within the parentheses refers to the specific trajectory group in the order it is listed (i.e., the first number within the parentheses refers to the shape of Trajectory 1). Based on the highest order statistically significant polynomial terms, the optimal order and shape of the trajectories for child-reported cognitive PCS was identified as: (3 3 3 3 1). The optimal order and shape of the trajectories for parent-reported cognitive PCS was: (3 2 3 3 1). The optimal order and shape of the trajectories for child-reported somatic PCS was: (3 3 3 3 1). The optimal order and shape of the trajectories for parent-reported somatic PCS was: (3 3 3 3 1). In this model, the probability of trajectory membership is not conditional on characteristics of the individual participants.

Figure 2

The Final Five-Group Multi-Trajectory Model of Child- and Parent-Reported Cognitive and Somatic PCS after Mild TBI and OI where each Trajectory is Defined by all Four Outcomes



Conditional Multi-Trajectory Model. After fitting the unconditional multi-trajectory model, demographic and injury variables were added to the model as risk factors to determine their influence on the probability of trajectory membership. Figure 3 shows the preferred model. Trajectory 1 (“low acute/resolved”), which is estimated to constitute 22.7% (mild TBI n = 90, OI n = 86) of the sample, is characterized by low levels of child- and parent-reported acute PCS that remain low and/or resolve over time. Trajectory 2 (“low acute/declining”), which constitutes 20.0% (mild TBI n = 86, OI n = 66) of the sample, displays similar trajectories of somatic PCS as Trajectory 1 but slightly higher levels of cognitive PCS that do not resolve over time. Trajectory 3 ("moderate acute/declining"), which constitutes 21.9% (mild TBI *n* = 123, OI *n* = 44), and Trajectory 4 ("moderate acute/persisting"), which constitutes 22.0% (mild TBI *n* = 115, OI *n* = 56), are characterized by moderate levels of acute PCS that decline slightly. Trajectory 4's trajectories of somatic PCS are similar to that of Trajectory 3, however, Trajectory 4's cognitive PCS, particularly those reported by parents, are distinctly higher than Trajectory 3's. Trajectory 5 ("high acute/persisting"), which constitutes 13.3% (mild TBI *n* = 92, OI *n* = 9), is distinguished from the other trajectories by its markedly elevated cognitive and somatic PCS. This trajectory declines slightly over time but remains distinctly higher than the other trajectories. Figure 4 shows the distributions of trajectory by injury group.

Figure 3

A Five-Group Multi-Trajectory Model of Child- and Parent-Reported Cognitive and Somatic PCS

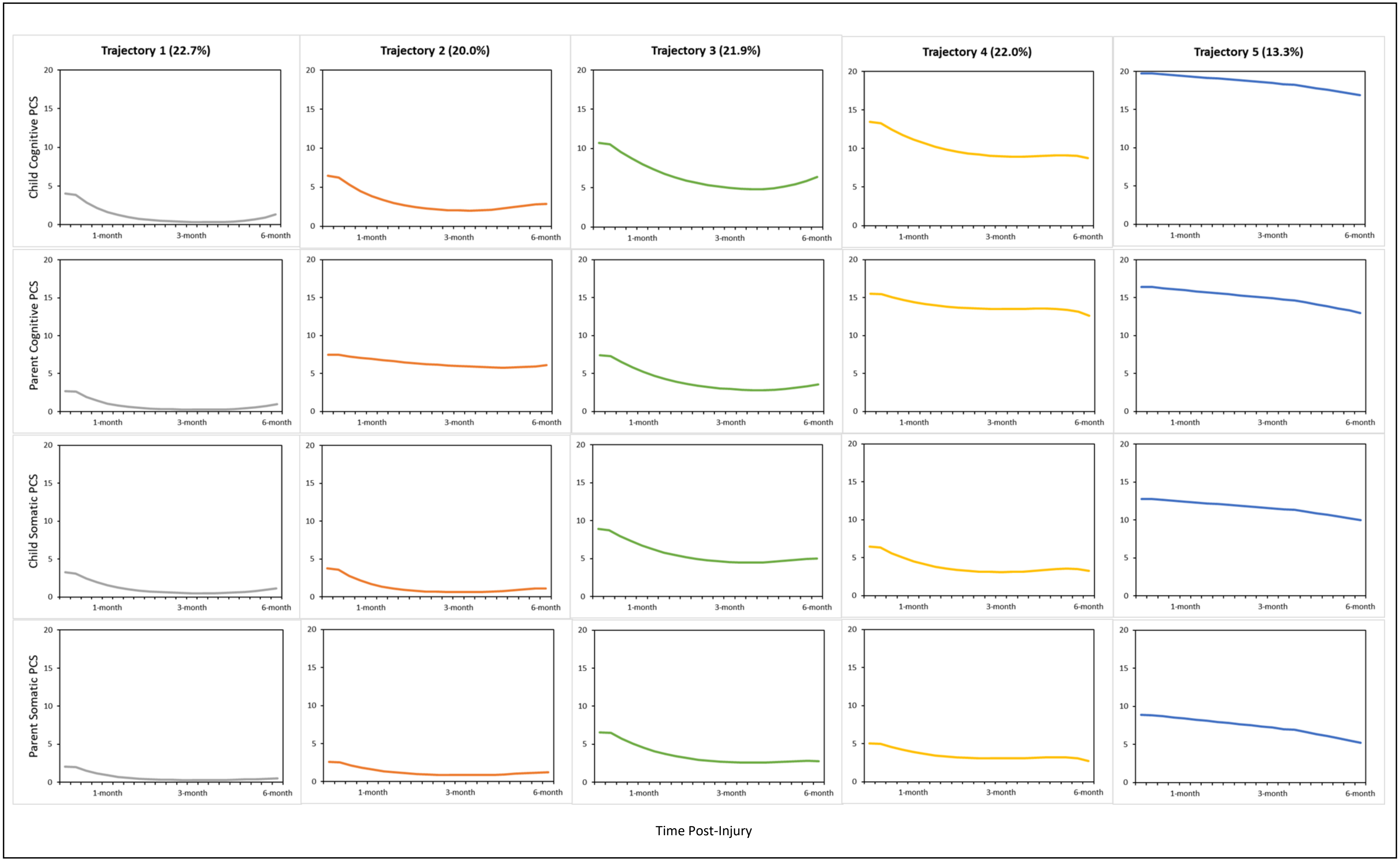
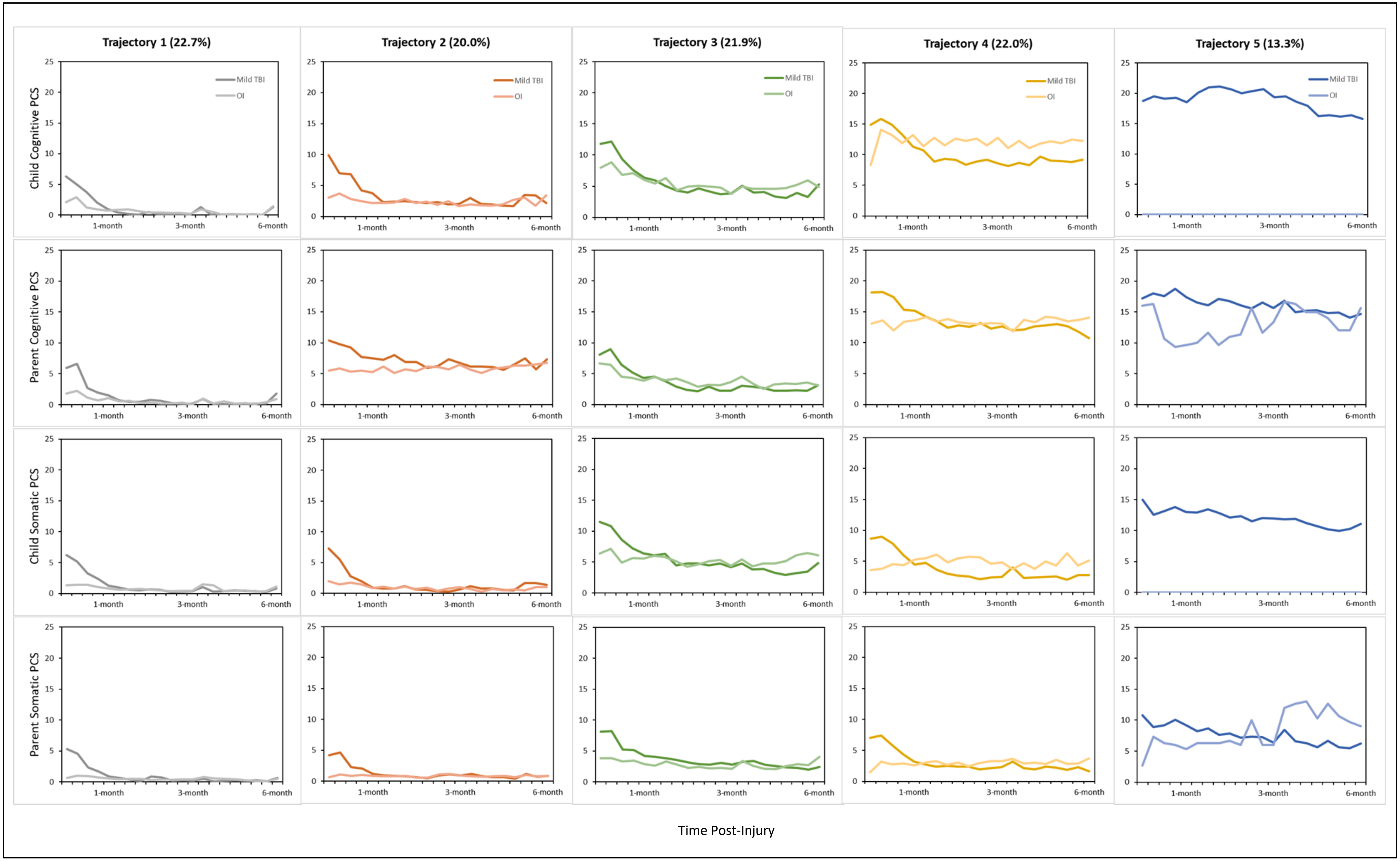


Figure 4

A Five-Group Multi-Trajectory Model of Child- and Parent-Reported Cognitive and Somatic PCS by Injury Group



Several demographic and injury variables predicted the probability of trajectory membership (see Table 8). Notably, injury group and retrospective cognitive symptoms were significantly associated with membership in several trajectories. Injury group was significantly associated with trajectory membership, such that being in the mild TBI group increased the likelihood of being assigned to Trajectories 3, 4, or 5, all of which are characterized by trajectories of moderate or high PCS, compared to Trajectory 1. Retrospective cognitive PCS were significantly associated with trajectory membership, such that higher levels of pre-injury symptoms increased the likelihood of being assigned to Trajectories 2, 3, 4, or 5, all of which are characterized by PCS trajectories that do not resolve over time, compared to Trajectory 1. Sex and retrospective somatic PCS were also significantly associated with membership in Trajectory 5, such that girls and children with higher levels of pre-injury somatic symptoms were more likely to experience a trajectory of high acute/persisting PCS. Some demographic factors, such as age, race, and parental education, and injury factors, such as concussion history, headache history, and migraine history, were not significant predictors of membership in any of the trajectories. Table 8 reports the significant parameter estimates of the trajectory membership probability component of the likelihood function, in which demographic and injury variables were added as predictors of trajectory membership.

Table 8

Significant Predictors of Trajectory Membership in Model 1

Trajectory	Coefficient	*t*-score	*p*-value
Trajectory 1: "Low acute/resolved"	-	-	-
Trajectory 2: "Low acute/declining"			
HBI Cognitive Retrospective	0.166	6.279	<.001
Trajectory 3: "Moderate acute/declining"			
Sex	0.814	3.249	.001
Injury Group	-1.181	-4.519	<.001
HBI Cognitive Retrospective	0.083	2.984	.003
HBI Somatic Retrospective	0.251	4.381	<.001
Trajectory 4: "Moderate acute/persisting"			
Injury Group	-0.654	-2.302	.021
HBI Cognitive Retrospective	0.289	10.400	<.001
Trajectory 5: "High acute/persisting"			
Sex	2.215	6.105	<.001
Injury Group	-2.661	-5.748	<.001
HBI Cognitive Retrospective	0.261	8.342	<.001
HBI Somatic Retrospective	0.304	4.778	<.001

Note. Higher scores indicate worse functioning on the retrospective cognitive and somatic symptoms scales.

Modeling Family and Parental Functioning as Predictors of PCS Trajectories

Model 2: Child- and Parent-Reported Cognitive and Somatic PCS after mild TBI

Unconditional Multi-Trajectory Model. See Appendix G for the results of the model building process for each outcome separately and the tests of model adequacy. Using the model building and selection procedure previously described, a six-group trajectory model emerged as the preferred unconditional model for Model 2. Each trajectory group is defined by a trajectory for the four symptom outcomes, assessed across the first 6-months post-injury. As before, cognitive PCS and somatic PCS were modeled as following the censored normal distribution where the censored minimum was set at the scale minimum and the censored maximum at the scale maximum, respectively (Loughran & Nagin, 2023). Models for up to six trajectory groups and quintic polynomial terms were estimated for each outcome. For both child- and parent-reported cognitive and somatic PCS, BIC increased with the addition of groups and captured the distinctive trajectories for each outcome that were revealed in the first stage of analysis, during which the number of subgroups for each model were estimated for each of the outcomes separately. The six-group model also performed well on the tests of model adequacy laid out in Nagin (2005). As such, the preferred multi-trajectory model included six trajectories. In this model, the probability of trajectory membership is not conditional on characteristics of the individual participants.

Conditional Multi-Trajectory Model. After fitting the unconditional multi-trajectory model, demographic and injury variables, as well as parental and family functioning variables, were added to the model as risk factors to determine their association with the probability of trajectory membership. Only demographic and injury variables that were identified as significant predictors of trajectory membership in the combined sample (i.e., Model 1) were included in the mild TBI sample (i.e., Model 2). Figure 5 shows the preferred model. Trajectory 1 ("low acute/resolved"), which is estimated to constitute 20.2% (n = 99) of the mild TBI sample, is characterized by low levels of child- and parent-reported acute PCS that remain low and largely resolve over time. Trajectory 2 ("low acute/declining"), which constitutes 13.3% (n = 62) of the mild TBI sample, displays similar declining trajectories of child- and parent-reported somatic symptoms as Trajectory 1 but slightly higher levels of child- and parent-reported cognitive symptoms that do not resolve by 6-months post-injury. Trajectory 3 ("moderate acute/elevated cognitive"), which constitutes 20.7% (n = 102), and Trajectory 4 ("moderate acute/declining"), which constitutes 22.2% (n = 107), are characterized by moderate levels of acute PCS that decline over time. Trajectory 3's trajectories of somatic PCS are similar to that of Trajectory 4; however, Trajectory 3's cognitive PCS, particularly those reported by parents, are distinctly higher than Trajectory 4's. Trajectory 5 ("high acute/declining"), which constitutes 17.5% (n =

86), is characterized by high acute PCS that modestly decline over time. Trajectory 6 (“high acute/persisting”; 6.2%; *n* = 29) is distinguished from the other groups by its markedly elevated PCS, particularly cognitive symptoms. This trajectory’s cognitive symptoms decline slightly over time, while the somatic symptoms remain stable, but all of its trajectories remain distinctly higher than the other trajectories.

Figure 5

A Six-Group Multi-Trajectory Model of Child- and Parent-Reported PCS after Mild TBI

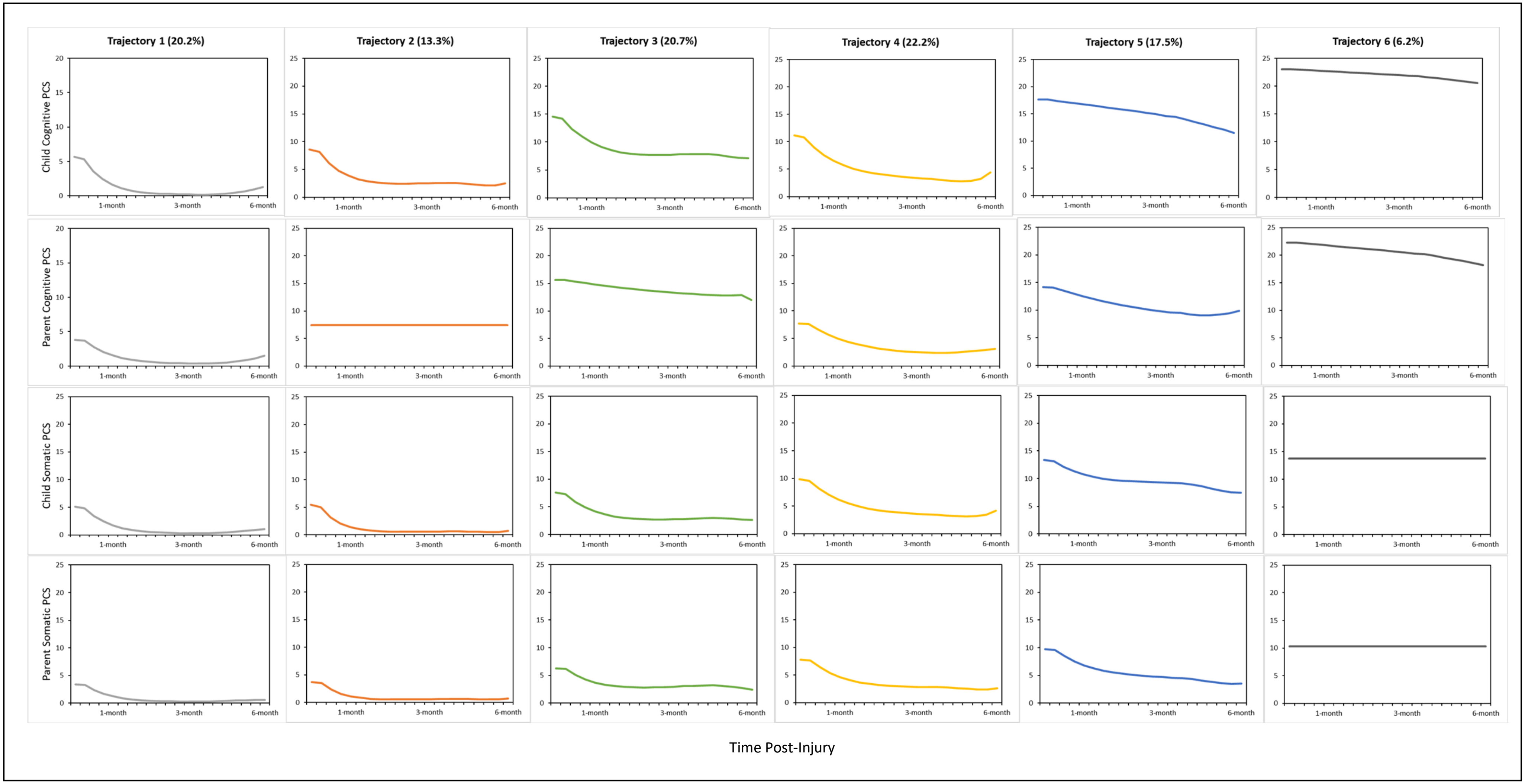


Table 9 displays demographic, injury, and parent/family information about each trajectory. Several differences between trajectories were identified using analysis of variance and chi-squared tests, as appropriate. The trajectories differed significantly in age ($F(5, 479) = 3.99$, $p = .002$, $\eta^2 = .04$ [medium effect]). After applying a Bonferroni correction, Tukey's test for multiple comparisons found that individuals in Trajectory 6 were significantly older than individuals in Trajectory 1 ($p = .002$). The trajectories also differed significantly in sex (χ^2 (5) = 53.86, $p < .001$, Cramer's V = .33 [moderate association]). Post-hoc tests found that males were more likely to be in Trajectory 2 ($p = .003$) or Trajectory 3 ($p = .002$), and females were more likely to be in Trajectories 5 ($p < .001$) or 6 ($p < .001$). The trajectories also differed significantly in race (χ^2 (25) = 39.02, $p = .037$, Cramer's V = .13 [weak association]); however, after applying a Bonferroni correction, no paired differences remained significant. The trajectories differed significantly in headache history (χ^2 (10) = 18.54, $p = .047$, Cramer's V = .14 [weak association]). Individuals in Trajectory 2 were less likely to have a history of headaches than those in the other trajectories ($p = .003$). The trajectories differed significantly in 5P clinical risk score ($F(5, 479) = 15.93$, $p = <.001$, $\eta^2 = .14$ [large effect]). The mean value of 5P score was significantly different between: Trajectories 1 and 5 ($p < .001$); Trajectories 1 and 6 ($p < .001$); Trajectories 2 and 5 ($p < .001$); Trajectories 2 and 6 ($p < .001$); Trajectories 3 and 5 ($p < .001$); and Trajectories 3 and 6 ($p = .001$). Trajectory 6 had the highest mean 5P score ($M = 7.45$, $SD = 2.11$), while Trajectory 2 had the lowest mean value ($M = 5.21$, $SD = 1.87$). The trajectories differed significantly in retrospective cognitive symptoms ($F(5, 479) = 43.78$, $p < .001$, $\eta^2 = .31$ [large effect]). Individuals in Trajectory 6 had significantly higher retrospective cognitive symptoms than those in Trajectory 1 ($p = .002$). The trajectories also differed significantly in retrospective somatic symptoms ($F(5, 479) = 21.47$, $p < .001$, $\eta^2 = .18$ [large effect]). The mean value was significantly different between: Trajectories 1 and 4 ($p < .001$); Trajectories 1 and 5 ($p < .001$); Trajectories 1 and 6 ($p < .001$); Trajectories 2 and 4 ($p = .001$); Trajectories 2 and 5 ($p < .001$); Trajectories 2 and 6 ($p < .001$); Trajectories 3 and 6 ($p < .001$); Trajectories 4 and 6 ($p < .001$); and Trajectories 5 and 6 ($p = .001$). Trajectory 6 had the highest mean retrospective somatic symptoms ($M = 6.83$, $SD = 5.70$), while Trajectory 2 had the lowest mean value ($M = 0.98$, $SD = 1.34$). The trajectories did not differ significantly in parental education, concussion history, migraine history or mechanism of injury.

Table 9

Demographic, Injury, and Parent/Family Profiles of the Mild TBI Sample by Trajectory

	Trajectory 1 "Low acute/ resolved"	Trajectory 2 "Low acute/ declining"	Trajectory 3 "Moderate acute/elevated cognitive"	Trajectory 4 "Moderate acute/ declining"	Trajectory 5 "High acute/ declining"	Trajectory 6 "High acute/ persisting"	Statistics		
	***n* = 99**	***n* = 62**	***n* = 102**	***n* = 107**	***n* = 86**	***n* = 29**	**F/χ^2**	***p***	**η^2/V[1]**
Age									
M (SD)	12.20 (2.33)	11.43 (2.48)	12.29 (2.56)	12.56 (2.34)	12.82 (2.75)	13.60 (2.41)	3.99*	.002	.04
Range	8.10-16.90	8.01-16.88	8.00-16.81	8.04-16.83	8.21-16.91	8.16-16.94			
Sex									
% male *(n)*	70.7 (70)	77.4 (48)	73.5 (75)	56.1 (60)	34.9 (30)	31.0 (9)	53.86*	<.001	.33
Race									
% Asian *(n)*	12.1 (12)	6.5 (4)	9.8 (10)	7.5 (8)	3.5 (3)	13.8 (4)	39.02*	.037	.13
% Black *(n)*	5.1 (5)	0.0 (0)	4.9 (5)	0.9 (1)	2.3 (2)	10.3 (3)			
% Hispanic *(n)*	1.0 (1)	0.0 (0)	2.9 (3)	0.9 (1)	4.7 (4)	6.9 (2)			
% Indigenous *(n)*	4.0 (4)	0.0 (0)	0.0 (0)	2.8 (3)	4.7 (4)	0.0 (0)			
% Other/Multi-racial *(n)*	11.1 (11)	17.7 (11)	11.8 (12)	8.4 (9)	15.1 (13)	3.5 (1)			
% White *(n)*	66.7 (66)	75.8 (47)	70.6 (72)	79.4 (85)	69.8 (60)	65.5 (19)			
Parental Education[2]									
% ≤ High School *(n)*	20.2 (20)	9.7 (6)	22.6 (23)	7.5 (8)	15.1 (13)	13.8 (4)	23.19	.080	.13
% Trades/College *(n)*	22.2 (22)	21.0 (13)	27.5 (28)	31.8 (34)	33.7 (29)	44.8 (13)			
% Bachelor's Degree *(n)*	40.4 (40)	51.6 (32)	34.3 (35)	41.1 (44)	32.6 (28)	27.6 (8)			
% >Bachelor's Degree *(n)*	17.2 (17)	17.7 (11)	15.7 (16)	19.6 (21)	18.6 (16)	13.8 (4)			
Concussion History									
% Had concussion *(n)*	23.3 (23)	25.8 (16)	31.4 (32)	29.0 (31)	24.4 (21)	44.8 (13)	9.72	.465	.10
Headache History									
% Had headache *(n)*	78.8 (78)	61.3 (38)	72.6 (74)	85.1 (91)	73.3 (63)	82.8 (24)	18.54*	.047	.14
Migraine History									
% Had migraine *(n)*	7.1 (7)	0.0 (0)	5.9 (6)	7.5 (8)	4.7 (4)	17.2 (5)	11.00	.051	.15
Injury Mechanism									
% Assault *(n)*	0.0 (0)	0.0 (0)	2.0 (2)	0.0 (0)	1.2 (1)	0.0 (0)	38.58	.534	.13
% Bicycle-related *(n)*	2.0 (2)	1.6 (1)	1.0 (1)	1.9 (2)	3.5 (3)	0.0 (0)			
% Fall *(n)*	40.4 (40)	45.2 (28)	49.0 (50)	41.1 (44)	38.4 (33)	58.6 (17)			

% MVC *(n)*	0.0 (0)	0.0 (0)	2.9 (3)	0.9 (1)	3.5 (3)	3.5 (1)			
% Struck object *(n)*	37.4 (37)	25.8 (16)	28.4 (29)	38.3 (41)	29.1 (25)	24.1 (7)			
% Struck person *(n)*	18.2 (18)	24.2 (15)	13.7 (14)	16.8 (18)	22.1 (19)	10.3 (3)			
% Other *(n)*	0.0 (0)	1.6 (1)	2.0 (2)	0.9 (1)	1.2 (1)	3.5 (1)			
% Unknown *(n)*	2.0 (2)	1.6 (1)	1.0 (1)	0.0 (0)	1.2 (1)	0.0 (0)			
5P Clinical Risk Score									
M (SD)	5.36 (1.91)	5.21 (1.87)	5.91 (1.74)	6.26 (1.85)	7.19 (1.60)	7.45 (2.11)	15.93*	<.001	.14
Range	2-10	2-9	1-10	2-11	2-11	3-11			
HBI Cognitive Retrospective									
M (SD)	3.48 (4.76)	8.97 (5.93)	14.59 (6.73)	5.64 (5.54)	9.88 (7.63)	16.10 (9.23)	43.78*	<.001	.31
Range	0-20	0-27	0-31	0-22	0-30	0-30			
HBI Somatic Retrospective									
M (SD)	1.17 (1.66)	0.98 (1.34)	2.42 (2.94)	3.03 (3.63)	4.03 (3.86)	6.83 (5.70)	21.47*	<.001	.18
Range	0-9	0-6	0-14	0-16	0-20	0-26			
Family Functioning									
M (SD)	17.33 (4.53)	18.74 (5.22)	20.09 (5.12)	18.43 (5.03)	19.55 (5.27)	20.24 (5.33)	3.96*	.002	.04
Range	12-28	12-34	12-37	12-35	12-37	12-32			
Parental Psychological Adjustment									
M (SD)	2.33 (3.01)	2.50 (2.38)	4.32 (3.85)	2.98 (2.96)	3.78 (3.26)	4.48 (4.06)	5.91*	<.001	.06
Range	0-21	0-10	0-24	0-15	0-19	0-16			
Parental Reactions to Children's Symptoms									
Protect									
M (SD)	1.69 (0.75)	1.71 (0.69)	1.67 (0.60)	1.84 (0.68)	1.81 (0.71)	2.15 (0.72)	2.84*	.015	.03
Range	0-4	0-4	0-3	1-4	0-4	0-4			
Monitor									
M (SD)	3.39 (0.61)	3.32 (0.64)	3.26 (0.71)	3.39 (0.62)	3.32 (0.63)	3.41 (0.61)	0.66	.651	.007
Range	2-4	1-4	1-4	1-4	1-4	2-4			
Minimize									
M (SD)	0.53 (0.54)	0.60 (0.48)	0.74 (0.60)	0.62 (0.56)	0.75 (0.58)	0.81 (0.79)	2.46*	.032	.03
Range	0-2	0-2	0-3	0-2	0-2	0-3			
Distract									
M (SD)	2.17 (0.81)	2.16 (0.75)	2.10 (0.77)	2.21 (0.75)	2.27 (0.61)	2.14 (0.74)	0.55	.737	.006
Range	0-4	0-4	0-4	0-4	0-4	0-3			
Parental Social Support									

M (SD)	58.08 (8.96)	56.21 (9.59)	52.19 (11.43)	55.92 (8.96)	51.70 (10.16)	51.41 (10.64)	6.42*	<.001	.06
Range	35-72	37-72	24-72	29-72	30-71	27-72			

Note. M = Mean; SD = standard deviation; MVC = motor vehicle collision; HBI = Health and Behaviour Inventory

[1] Eta squared*;* Cramer's V

[2] Primarily based on maternal education, paternal education if maternal not available

* Significant group difference ($p < .05$)

Several parental and family functioning variables predicted the probability of trajectory membership (see Table 10). Notably, retrospective cognitive symptoms and retrospective somatic symptoms were significantly associated with membership in most of the trajectories. Retrospective cognitive symptoms were significantly associated with membership, such that higher retrospective cognitive symptoms increased the likelihood of being assigned to Trajectories 2, 3, 5, or 6, compared to Trajectory 1. Retrospective somatic symptoms were significantly associated with trajectory membership, such that lower somatic symptoms increased the likelihood of being assigned to Trajectory 2, while more somatic symptoms increased the likelihood of being assigned to Trajectories 4, 5, or 6, relative to Trajectory 1. The 5P clinical risk score was significantly associated with trajectory membership, such that higher scores, which reflect an increased risk for persisting symptoms, increased the likelihood of being assigned to Trajectories 3, 5, or 6. Parental social support was significantly associated with group membership, such that lower scores, which reflect less parental support, increased the likelihood of being assigned to Trajectories 3, 4, 5, or 6, all of which are characterized by trajectories of moderate or high PCS. Parental psychological functioning was significantly associated with trajectory membership, such that higher scores, which indicate more retrospective psychological distress, increased the likelihood of being assigned to Trajectory 3, the “moderate acute/elevated cognitive” trajectory. Finally, parental protectiveness was also associated with trajectory membership, such that higher scores, which reflect more protectiveness, increased the likelihood of being assigned to Trajectory 6, the “high acute/persisting” trajectory. Some factors, including sex, mechanism of injury, general family functioning, parental monitoring, parental minimizing, and parental distracting were not significant predictors of membership in any of the trajectories.

Table 10 reports the significant parameter estimates of the trajectory membership probability component of the likelihood function, in which demographic/injury factors and parental/family functioning were added as predictors of trajectory membership.

Table 10

Significant Predictors of Trajectory Membership in Model 2

Trajectory	Coefficient	*t*-score	*p*-value
Trajectory 1: "Low acute/resolved"	-	-	-
Trajectory 2: "Low acute/declining"			
HBI Cognitive Retrospective	0.198	5.481	<.001
HBI Somatic Retrospective	-0.284	-2.325	.020
Trajectory 3: "Moderate acute/elevated cognitive"			
HBI Cognitive Retrospective	0.293	7.988	<.001
5P Clinical Risk Score	0.333	2.754	.006
Parental Social Support	-0.068	0.020	.001
Parental Psychological Adjustment	0.128	2.040	.041
Trajectory 4: "Moderate acute/declining"			
HBI Somatic Retrospective	0.246	3.047	.002
Parental Social Support	-0.036	-2.026	.043
Trajectory 5: "High acute/declining"			
HBI Cognitive Retrospective	0.184	5.002	<.001
HBI Somatic Retrospective	0.205	2.397	.017
5P Clinical Risk Score	0.467	3.747	<.001
Parental Social Support	-0.079	-3.891	<.001
Trajectory 6: "High acute/persisting"			
HBI Cognitive Retrospective	0.294	6.102	<.001
HBI Somatic Retrospective	0.244	2.574	.010
5P Clinical Risk Score	0.700	3.630	<.001
Parental Social Support	-0.074	-2.694	.007
Parental Protectiveness	1.535	3.268	.001

Note. Higher scores indicate better functioning on the parental social support scale, while higher scores indicate worse functioning on the retrospective cognitive and somatic symptoms scales, 5P clinical risk score scale, and parental psychological adjustment scale.

Model 3: Child- and Parent-Reported Cognitive and Somatic PCS after OI

Unconditional Multi-Trajectory Model. See Appendix G for the results of the model building process for each outcome separately and the tests of model adequacy. Using the model building and selection procedure previously described, a five-group trajectory model emerged as the preferred unconditional model for Model 3. Each trajectory group is defined by a trajectory for the four symptom outcomes. As before, cognitive and somatic PCS were modeled as following the censored normal distribution where the censored minimum was set at the scale minimum and the censored maximum at the scale maximum, respectively (Loughran & Nagin, 2023). Models for up to six trajectory groups and quintic polynomial terms were estimated for each outcome. For both child- and parent-reported cognitive and somatic PCS, BIC increased with the addition of groups and captured the distinctive trajectories for each outcome that were revealed in the first stage of analysis, during which the number of subgroups for each model were estimated for each of the outcomes separately. The five-group model also performed well on the tests of model adequacy laid out in Nagin (2005). As such, the preferred multi-trajectory model included five trajectories. In this model, the probability of trajectory membership is not conditional on characteristics of the individual participants.

Conditional Multi-Trajectory Model. After fitting the unconditional multi-trajectory model, demographic and injury variables, as well as parental and family functioning variables, were added to the model as risk factors to determine their influence on the probability of trajectory membership. Only demographic and injury variables that were identified as significant predictors of trajectory membership in the combined sample (i.e., Model 1) were included in the OI sample (i.e., Model 3). Figure 6 shows the preferred model. Trajectory 1 ("low acute/resolved"), which is estimated to constitute 31.1% (n = 79) of the OI sample, is characterized by low levels of child- and parent-reported acute PCS that remain low and largely resolve over time. Trajectory 2 ("low acute/declining"), which constitutes 21.4% (n = 54) of the sample, displays slightly higher levels of child- and parent-reported PCS than Trajectory 1 that do not resolve completely by 6-months post-injury. Trajectory 3 ("low acute/persisting"), which constitutes 26.0% (n = 65), and Trajectory 4 ("moderate acute/persisting"), which constitutes

16.3% (*n* = 41), are both characterized by PCS trajectories that remain stable over time. Trajectory 4 is distinguished from Trajectory 3 by higher levels of cognitive PCS, particularly those reported by parents. Trajectory 5 (“high acute/persisting”) which constitutes 5.1% (*n* = 13), is distinguished from the other trajectories by its markedly elevated PCS that remain stable and/or increase over time.

Figure 6

A Five-Group Multi-Trajectory Model of Child- and Parent-Reported PCS after OI

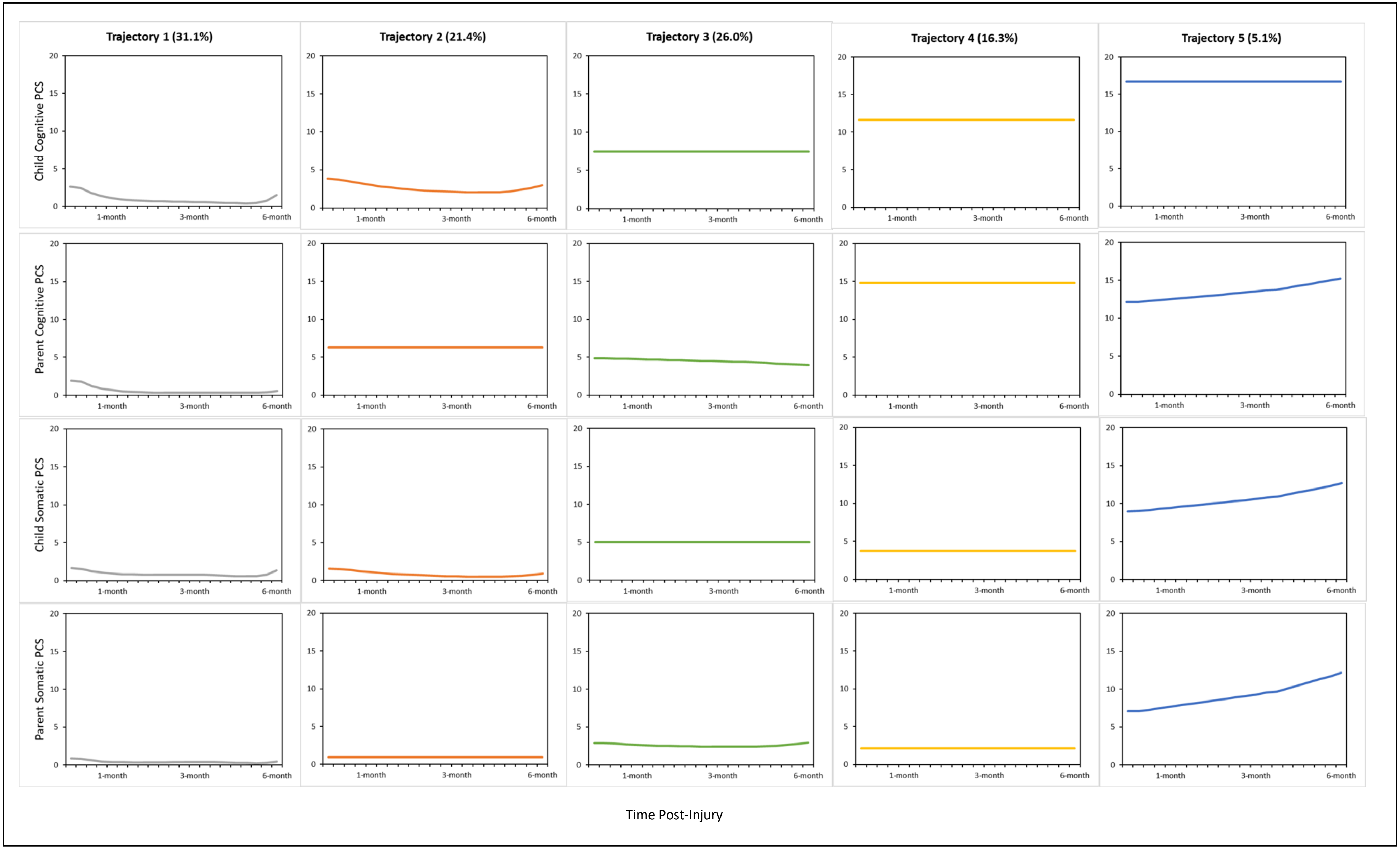


Table 11 displays demographic, injury, and parent/family information for each trajectory. Several differences between trajectories were identified using analysis of variance and chi-squared tests, as appropriate. The trajectories differ significantly in age (F(4, 247) = 4.41, p = .002, η^2 = .07 [medium effect]), however, after applying a Bonferroni correction, no significant differences were found between trajectories in age. The trajectories differed significantly in sex (χ^2 (4) = 20.52, p < .001, Cramer's V = .29 [moderate association]). Post-hoc tests found that males were more likely to be in Trajectory 2 (p < .001) and less likely to be in Trajectory 3 (p < .001). The trajectories differed significantly in 5P clinical risk score (F(4, 247) = 11.54, p = <.001, η^2 = .16 [large effect]). The mean value of 5P score was significantly different between: Trajectories 1 and 3 (p < .001); 2 and 3 (p < .001); 2 and 5 (p = .001); and 3 and 4 (p = .001). Trajectory 5 had the highest mean 5P score (*M* = 4.54, *SD* = 2.03), while Trajectory 2 had the lowest mean value (*M* = 2.59, *SD* = 1.35). The trajectories differed significantly in retrospective cognitive symptoms (F(4, 247) = 36.35, p < .001, η^2 = .37 [large effect]). The mean value of retrospective cognitive symptoms was significantly different between: Trajectories 1 and 2 (p < .001); 1 and 3 (p = .003); 1 and 4 (p < .001); 1 and 5 (p < .001); 2 and 4 (p < .001); 3 and 4 (p < .001); and 3 and 5 (p = .001). Trajectory 4 had the highest mean retrospective cognitive symptoms (*M* = 14.98, *SD* = 7.08), while Trajectory 1 had the lowest mean value (*M* = 2.73, *SD* = 4.49). The trajectories also differed significantly in retrospective somatic symptoms (F(4, 247) = 21.96, p < .001, η^2 = .26 [large effect]). The mean value of retrospective somatic symptoms was significantly different between: Trajectories 1 and 3 (p < .001); 1 and 5 (p < .001), 2 and 3 (p = .001); 2 and 5 (p < .001); 3 and 5 (p < .001); and 4 and 5 (p < .001). Trajectory 5 had the highest mean retrospective somatic symptoms (*M* = 8.15, *SD* = 6.97), while Trajectory 1 had the lowest mean retrospective somatic symptoms (*M* = 0.99, *SD* = 1.84). The trajectories did not differ significantly in race, parental education, concussion history, headache history, migraine history or mechanism of injury.

Table 11

Demographic, Injury, and Parent/Family Profiles of the OI Sample by Trajectory

	Trajectory 1 "Low acute/ resolved"	Trajectory 2 "Low acute/ declining"	Trajectory 3 "Low acute/persisting"	Trajectory 4 "Moderate acute/ persisting"	Trajectory 5 "High acute/ persisting"	Statistics		
	***n* = 79**	***n* = 54**	***n* = 65**	***n* = 41**	***n* = 13**	***F*/χ^2**	***p***	**η^2/V[1]**
Age								
M (SD)	12.92 (2.33)	12.34 (1.88)	12.87 (2.11)	11.54 (2.41)	13.89 (1.95)	4.41*	.002	.07
Range	8.05-16.96	9.43-15.68	8.34-16.82	8.21-16.82	10.96-16.83			
Sex								
% male *(n)*	49.4 (39)	75.9 (41)	36.9 (24)	63.4 (26)	61.5 (8)	20.52*	<.001	.29
Race								
% Asian *(n)*	12.7 (10)	5.6 (3)	7.7 (5)	4.9 (2)	0.0 (0)	21.64	.360	.15
% Black *(n)*	3.8 (3)	0.0 (0)	0.0 (0)	2.4 (1)	7.7 (1)			
% Hispanic *(n)*	7.6 (6)	3.7 (2)	4.6 (3)	0.0 (0)	7.7 (1)			
% Indigenous *(n)*	1.3 (1)	0.0 (0)	3.1 (2)	0.0 (0)	0.0 (0)			
% Other/Multi-racial *(n)*	15.2 (12)	14.8 (8)	10.7 (7)	14.6 (6)	0.0 (0)			
% White *(n)*	59.5 (47)	75.9 (41)	73.9 (48)	78.1 (32)	84.6 (11)			
Parental Education[2]								
% ≤ High School *(n)*	16.5 (13)	11.1 (6)	16.9 (11)	14.6 (6)	15.4 (2)	13.81	.313	.14
% Trades/College *(n)*	21.5 (17)	33.3 (18)	32.3 (21)	41.5 (17)	38.5 (5)			
% Bachelor's Degree *(n)*	46.8 (37)	27.8 (15)	29.2 (19)	29.3 (12)	23.1 (3)			
% >Bachelor's Degree *(n)*	15.2 (12)	27.8 (15)	21.5 (14)	14.6 (6)	23.1 (3)			
Concussion History								
% Had concussion *(n)*	22.8 (18)	27.8 (15)	41.5 (27)	17.1 (7)	30.8 (4)	9.42	.052	.19
Headache History								
% Had headache *(n)*	76.0 (60)	75.9 (41)	81.5 (53)	73.2 (30)	92.3 (12)	2.88	.578	.11
Migraine History								
% Had migraine *(n)*	6.3 (5)	1.9 (1)	12.3 (8)	4.9 (2)	15.4 (2)	6.62	.157	.16
Injury Mechanism								
% Assault *(n)*	0.0 (0)	0.0 (0)	1.5 (1)	0.0 (0)	0.0 (0)	33.66	.212	.21
% Bicycle-related *(n)*	3.8 (3)	1.9 (1)	7.7 (5)	2.4 (1)	7.7 (1)			
% Fall *(n)*	63.3 (50)	40.7 (22)	41.5 (27)	58.5 (24)	46.2 (6)			

% MVC *(n)*	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)			
% Struck object *(n)*	13.9 (11)	27.8 (15)	27.7 (18)	14.6 (6)	15.4 (2)			
% Struck person *(n)*	8.9 (7)	11.1 (6)	6.2 (4)	19.5 (8)	15.4 (2)			
% Other *(n)*	6.3 (5)	7.4 (4)	12.3 (8)	2.4 (1)	7.7 (1)			
% Unknown *(n)*	1.3 (1)	5.6 (3)	3.1 (2)	2.4 (1)	7.7 (1)			
5P Clinical Risk Score								
M (SD)	3.14 (1.44)	2.59 (1.35)	4.25 (1.78)	3.07 (1.31)	4.54 (2.03)	11.54*	<.001	.16
Range	1-7	1-6	1-9	1-6	3-9			
HBI Cognitive								
Retrospective	2.73 (4.49)	7.20 (5.72)	6.20 (5.55)	14.98 (7.08)	13.15 (6.43)	36.35*	<.001	.37
M (SD)	0-29	0-19	0-21	0-29	0-23			
Range								
HBI Somatic Retrospective								
M (SD)	0.99 (1.84)	1.17 (1.89)	3.20 (3.42)	1.98 (2.16)	8.15 (6.97)	21.96*	<.001	.26
Range	0-9	0-8	0-16	0-7	0-25			
Family Functioning								
M (SD)	17.46 (4.62)	18.61 (5.64)	19.06 (5.56)	20.07 (5.04)	21.54 (5.72)	2.85*	.024	.04
Range	12-28	12-35	12-35	12-33	12-30			
Parental Psychological Adjustment								
M (SD)	2.27 (2.94)	2.93 (2.76)	2.57 (2.73)	3.74 (3.83)	4.31 (3.99)	2.43*	.048	.04
Range	0-14	0-11	0-11	0-18	0-13			
Parental Reactions to Children's Symptoms								
Protect								
M (SD)	1.26 (0.69)	1.28 (0.58)	1.58 (0.63)	1.65 (0.77)	1.80 (0.96)	4.67*	.001	.07
Range	0-3	0-3	0-4	0-4	0-3			
Monitor								
M (SD)	3.13 (0.87)	3.21 (0.60)	3.34 (0.65)	3.33 (0.69)	3.25 (0.88)	0.92	.453	.01
Range	0-4	1-4	1-4	2-4	2-4			
Minimize								
M (SD)	0.63 (0.58)	0.63 (0.48)	0.77 (0.55)	0.74 (0.59)	0.94 (0.69)	1.42	.227	.02
Range	0-3	0-2	0-2	0-2	0-2			
Distract								
M (SD)	2.19 (0.85)	2.14 (0.69)	2.37 (0.63)	2.40 (0.65)	2.44 (0.92)	1.44	.220	.02
Range	0-4	0-4	0-4	1-4	1-4			

Parental Social Support								
M (SD)	56.72 (9.72)	56.0 (10.38)	52.87 (11.05)	55.16 (9.71)	49.31 (13.14)	2.32	.058	.04
Range	22-72	30-71	25-72	37-71	22-72			

Note. M = Mean; SD = standard deviation; MVC = motor vehicle collision; HBI = Health and Behaviour Inventory

[1] Eta squared*;* Cramer's V

[2] Primarily based on maternal education, paternal education if maternal not available

* Significant group difference (*p* < .05)

Several parental and family functioning variables predicted the probability of trajectory membership (see Table 12). Notably, retrospective cognitive symptoms were significantly associated with membership in all of the trajectories. Retrospective cognitive symptoms were significantly associated with trajectory membership, such that more pre-injury cognitive symptoms increased the likelihood of being assigned to Trajectories 2, 3, 4, or 5, compared to Trajectory 1. Retrospective somatic symptoms were significantly associated with trajectory membership, such that more somatic symptoms increased the likelihood of being assigned to Trajectory 5, relative to 1. Sex and mechanism of injury were significantly associated with trajectory membership, such that being female or sustaining an injury through a fall increased the likelihood of being assigned to Trajectory 2. The 5P clinical risk score was significantly associated with trajectory membership, such that higher scores increased the likelihood of being assigned to Trajectories 3 or 5. Finally, parental social support was also significantly associated with trajectory membership, such that lower scores, which reflect less parental support, increased the likelihood of being assigned to Trajectory 5. Some factors, including general family functioning, parental protectiveness, parental monitoring, parental minimizing, parental distracting, and parental psychological adjustment, were not significant predictors of trajectory membership. Table 12 reports the significant parameter estimates of trajectory membership probability component of the likelihood function, in which demographic/injury factors and parental/family functioning were added as predictors of trajectory membership.

Table 12

Significant Predictors of Trajectory Membership in Model 3

Trajectory	Coefficient	*t*-score	*p*-value
Trajectory 1: "Low acute/resolved"	-	-	-
Trajectory 2: "Low acute/declining"			
Sex	-1.078	-1.984	.047
Mechanism of Injury	0.175	2.032	.042
HBI Cognitive Retrospective	0.209	4.284	<.001
Trajectory 3: "Low acute/persisting"			
HBI Cognitive Retrospective	0.146	2.974	.003
5P Clinical Risk Score	0.461	2.796	.005
Trajectory 4: "Moderate acute/persisting"			
HBI Cognitive Retrospective	0.389	6.916	<.001
Trajectory 5: "High acute/persisting"			
HBI Cognitive Retrospective	0.289	3.985	<.001
HBI Somatic Retrospective	0.359	2.909	.004
5P Clinical Risk Score	0.621	2.060	.039
Parental Social Support	-0.080	-2.064	.039

Note. Higher scores indicate better functioning on the parental social support scale, while higher scores indicate worse functioning on the retrospective cognitive and somatic symptoms scales, and the 5P clinical risk score scale.

Discussion

The current study identifies trajectories of PCS in children after mild TBI and OI and delineates the nature of predictors of these distinct trajectories. Specifically, children with mild TBI displayed trajectories characterized by significantly more severe and longer-lasting PCS compared to children with OI. We also found that certain parental and family factors predict PCS trajectories, such that better parental and family functioning was associated with a more rapid recovery for both children with mild TBI and those with OI. Our results are generally consistent with previous studies but build on those findings by using multi-trajectory modeling of the four jointly considered symptom outcomes and including demographic and family factors as predictors of PCS recovery trajectories.

In Model 1, we found that sustaining a mild TBI increased the likelihood of being assigned to Trajectories 3 ("moderate acute/declining"), 4 ("moderate acute/persisting"), or 5 ("high acute/persisting"), all of which are characterized by trajectories of moderate or high PCS, compared to Trajectory 1 ("low acute/resolved"). Our finding that injury group was a significant predictor of trajectory membership is consistent with the literature. Although PCS are non-specific and may be observed following injuries not involving the head, previous studies consistently report that on average children with mild TBI display more severe and longer-lasting PCS than children with OI (Taylor et al., 2010; Yeates et al., 2009; Yeates et al., 2012). Collectively, these findings suggest that PCS after mild TBI cannot be fully attributed to the effects of general trauma.

A recent systematic review and meta-analysis found that girls are at increased risk of persisting PCS (Chadwick et al., 2022). In the combined mild TBI and OI sample (i.e., Model 1), we found that sex predicted trajectory membership, such that girls were more likely to experience a trajectory of high acute/persisting PCS. However, in the OI only sample (i.e., Model 3), we found that girls were significantly more likely to be assigned to the low acute/declining PCS trajectory. Sex was not a significant predictor of trajectory membership in the mild TBI only sample (i.e., Model 2); however, sex could be linked to the experience of PCS in several ways. First, sex differences in PCS may be related to differences in how boys and girls are socialized to report symptoms, with girls more frequently reporting somatic symptoms than boys in uninjured samples (McNally et al., 2013; Yeates et al., 2022). Specifically, girls tend to report higher levels of anxiety and depression compared to boys (Altemus et al., 2014), which could prolong recovery from mild TBI (Lumba-Brown et al., 2018). Physiologic, metabolic, neuroanatomic, and hormonal sex differences could also be responsible for differences in the brain's response to injury between boys and girls (Yeates et al., 2022). Overall, sex is likely an important factor for informing our understanding of the differences between high-risk and low-risk groups, although other factors, such as injury group, need to be jointly considered to create a complete picture of who is at highest risk of experiencing PCS.

In all three models (i.e., combined mild TBI and OI, mild TBI only, and OI only samples), retrospective cognitive and somatic symptoms were significant predictors of trajectory membership, such that children with higher levels of pre-injury symptoms were more likely to experience a symptom trajectory with more and longer lasting PCS. These findings are consistent with those of previous studies. Children's pre-injury symptoms have consistently been shown to be related to PCS, with higher levels of pre-injury PCS predicting higher levels of post-injury PCS (McNally et al., 2013; Taylor et al., 2010). Other noninjury-related factors that could be captured under the umbrella term of PCS, such as a pre-injury psychiatric history (Ponsford et al., 1999), premorbid stressors (Ponsford et al., 1999), pre-existing learning problems (Ponsford et al., 1999), and pre-injury cognitive ability (Fay et al., 2010) have also been shown to be associated with PCS after mild TBI, such that children with worse functioning pre-injury have worse outcomes after injury. The experience of PCS after an injury may result in heightened distress in children with a history of pre-existing concerns, who may have greater anxiety sensitivity, less adaptive coping skills, lower stress tolerance, or less cognitive reserve, all of which may reduce their capacity to effectively cope with the brain injury. This in turn may further exacerbate and prolong PCS.

In both the mild TBI (i.e., Model 2) and OI (i.e., Model 3) samples, the 5P clinical risk score was significantly associated with trajectory membership. In the mild TBI sample, higher 5P scores, which reflect an increased risk for persisting symptoms, predicted membership in Trajectories 3 ("moderate acute/elevated cognitive"), 5 ("high acute/declining") or 6 ("high acute/persisting"). In the OI sample, higher 5P scores predicted membership in Trajectories 3 ("low acute/persisting") or 5 ("high acute/persisting"). The 5P score predicts future persisting PCS by assessing nine variables: age, sex, prior concussion and symptom duration, migraine history, answering questions slowly, difficulty with balance, headache, sensitivity to noise, and fatigue (Zemek et al., 2016). In general, our findings are consistent with those of previous studies suggesting that female sex, older age, prior history of concussion or migraine, headache, and sensitivity to noise are associated with persisting PCS (Chrisman et al., 2013; Scopaz & Hatzenbuehler, 2013; Zemek et al., 2013). The 5P score may not be specific to mild TBI, but could serve as a more general predictor of persisting symptoms, suggesting that some risk factors for PCS may cut across injury types.

Several parental and family factors were identified as significant predictors of trajectory membership. In the mild TBI sample (i.e., Model 2), higher scores on the measure of parental adjustment, which indicates more retrospective psychological distress, and higher parental protectiveness increased the likelihood of being assigned to a trajectory characterized by moderate or high levels of PCS. Children of parents with pre-existing psychological difficulties may experience heightened levels of distress, more anxiety sensitivity, and lower stress tolerance as the result of a variety of mechanisms, such as genetic predisposition or parental modeling. Previous studies conducted with adults have suggested that anxiety mediates the prolongation of concussion symptoms (Edmed & Sullivan, 2012; Wood et al., 2011). Parental protectiveness has also been associated with increased pain intensity and functional disability for children with chronic pain (Noel et al., 2015; Sieberg et al., 2011). Parents may engage in protective behaviours to decrease their own distress (Noel et al., 2016), and this may be especially true for parents with poor psychological adjustment and higher levels of premorbid distress. Although parental distress and protectiveness are expected and normal responses after a child's injury, these behaviours may become maladaptive when they persist beyond the acute period after injury, exacerbating and prolonging children's PCS.

Interestingly, parental social support was a significant predictor of trajectory membership for both mild TBI (i.e., Model 2) and OI (i.e., Model 3), such that lower scores, which reflect less parental support, increased the likelihood of being assigned to a trajectory characterized by moderate or high levels of PCS. Our finding that inadequate parental social support may hinder injury recovery, regardless of the type of injury, is consistent with previous research (Chadwick, 2020). Social support likely aids in reducing PCS, but not in a way that is specific to mild TBI. Although PCS are not specific to head injuries, children with injuries to regions of the body other than the head are unlikely to exhibit the same level of PCS as children who have sustained a brain injury. Thus, social support is likely to be especially important for children during mild TBI recovery. Social support is a complex construct that differentially facilitates health outcomes based on several factors. For example, boys and girls tend to prefer different types of support from different sources, and this preference changes as children age (Malecki & Demary, 2002). Additionally, the quality of the relationship between a caregiver and the recipient of support, as well as the gender of the provider, may influence the quality of social support and its physiological impact (Hogan et al., 2002). Although our results provide further confirmation of the beneficial role that perceived social support plays in facilitating health outcomes, the precise mechanisms by which social support facilitates these outcomes require further investigation.

Clinical Implications

This study demonstrates that demographic and parental and family factors play an important role in predicting PCS trajectories after mild TBI. Identification of different symptom trajectories and the influence of parental and family functioning as predictors of those trajectories provides guidance for clinicians in developing family-based treatments. In particular, these findings point to the need for clinicians to assess noninjury-related factors (e.g., parental and family functioning) when trying to predict outcomes. These findings also suggest that interventions focused on parental protectiveness, psychological adjustment, or social support, but not global family functioning, could be particularly beneficial for improving outcomes and warrant further investigation and development. Individual-level predictions together with group-level probabilities and trajectory estimates may aid clinicians in early outcome prediction and the opportunity to manage injuries with appropriately targeted and timely interventions.

Limitations

The current results should be interpreted considering several limitations. First, the A-CAP study recruited participants from EDs. Children presenting for medical care at EDs may have more severe injuries than those who present to other healthcare settings or who do not seek medical attention after injury. Because many mild TBIs or other injuries go undetected or do not receive medical attention (McCrea et al., 2004), the A-CAP study did not capture all children with mild TBI/concussion or OI, so the findings may only generalize to children seen in ED settings. Additionally, this study's recruitment hours (i.e., 8am-11pm) could result in some selection bias, although the sample should be representative of children seeking care for mild TBI/concussion and OI during those times.

Study participants also exhibited heterogeneity in age at injury. Although the trajectories identified in this project varied in participant age, age was not a significant predictor of trajectory group membership. Age may moderate the relationship between parental and family functioning and children's PCS, but our ability to investigate age as a moderator was limited by the available sample size.

Attrition over time was substantial in the study, although this was expected given its longitudinal nature. Although attrition was expected given the study's longitudinal design, this may have introduced unmeasured bias into the results. However, comparisons of children who were and were not included in analyses suggest that attrition was not associated with significant bias. Moreover, group-based multi-trajectory modeling made use of participants who had at least one post-injury symptom rating, helping to reduce any attrition bias.

Another limitation involves the measurement of parental and family functioning and children's pre-injury symptoms. Pre-injury family functioning, pre-injury parental psychological adjustment, and children's pre-injury symptoms were rated retrospectively by parents. Retrospective ratings may be subject to recall biases, particularly during a stressful time, such as shortly after a child's injury. Most measures were completed by parents, who may have provided different ratings than their children would have on similar measures (e.g., children's pre-injury symptoms). Additionally, the measures assessing parental and family functioning were administered at the post-acute assessment, which does not account for changes in parental or family functioning post-injury and how those changes may impact or be affected by children's recovery. A child's injury likely has a bidirectional effect on parents and the family, such that parental and family functioning are influenced by and in turn influence recovery after mild TBI (Beauchamp et al., 2021; Chadwick et al., 2023). Future work should investigate the potential reciprocal interactions between PCS and the family environment after mild TBI.

The current project focused on the association of parental and family functioning with children's PCS recovery trajectories; however, other factors may be relevant to recovery, either directly or indirectly. For example, child neurobiological and psychological factors could also play an important role in predicting PCS recovery and should be included in future investigations to better understand the complex recovery process after mild TBI.

Finally, we acknowledge that the models presented in this study do not depict actual groups or trajectories of individuals. Group-based multi-trajectory modeling identifies an approximation of latent groups based on distinctive features of the data. There is no "true" number of groups in the sample population, so group identification is probabilistic, not certain. Although the best-fitting models were chosen for presentation in the current study, there remains the potential for misclassification of participants.

Conclusion

In conclusion, the current study adds to the existing literature by showing that demographic and parental and family factors play an important role in predicting PCS trajectories after mild TBI. Generally, the results were consistent with our hypotheses that children with mild TBI would demonstrate trajectories reflecting higher levels of PCS compared to children with OI and that better parental and family functioning would be associated with PCS trajectories showing lower acute levels of PCS and more rapid recovery for both children with mild TBI and OI.

Further research is needed to better characterize injury-related and noninjury-related factors that influence symptom recovery after mild TBI. Attention should be paid to those factors that may contribute to the development of persisting PCS. Of particular importance is to increase our understanding of how family factors may vary post-injury and how any changes may affect children's recovery course. It will also be important to develop family-based interventions and to appropriately target those interventions. Such work will help to develop a more complete understanding of risk and resiliency factors following pediatric mild TBI.

While group-based trajectory modeling has seen increasing adoption in clinical research, to the best of our knowledge this is the first study to jointly model multiple symptom outcomes across time and to examine parental and family functioning as predictors of those outcomes after mild TBI. This detailed examination of multiple outcomes provides a fuller picture of children's symptom trajectories over time. Given our results, we believe that group-based multi-trajectory modeling could be used as a tool to more clearly identify factors that put children at greater risk for poor recovery and could in turn enable the development of targeted, proactive interventions for individuals in all risk groups.

Chapter 4: Concluding Remarks

Summary of Findings

This dissertation sought to better understand the association between parental and family functioning and post-concussive symptoms (PCS) after pediatric mild traumatic brain injury (TBI). Study 1 consists of a scoping review that examined the existing literature on the relationship between parental and family functioning and pediatric mild TBI to determine relevant parental and family factors, summarize findings, and identify areas for further research. Study 1 identified 15 empirical studies (mild TBI n = 2,222; control n = 347) that addressed three main questions: (1) Does mild TBI result in more parental distress or poorer family functioning than other injuries?; (2) Does pre-injury or acute parental distress and family functioning predict PCS after mild TBI?; and (3) Does acute PCS predict later parental distress and family functioning?

The first question of the scoping review sought to understand the influence of injury type on parental and family functioning. Three of the studies included in the review assessed parental and family functioning after mild TBI compared to children with other injuries, including extracranial injuries (Barlow et al., 2010), orthopedic injuries (OI; Ganesalingam et al., 2008), and superficial injuries to the head (Yumul et al., 2020). Overall, these three studies did not report significant differences in parental or family functioning after injury between the mild TBI and comparison groups, except for one result when mild TBI with loss of consciousness (LOC) was analyzed separately (Ganesalingam et al., 2008). Although the domains of parental and family functioning assessed, the type of comparison group, and the time post-injury varied between studies, the results tentatively suggest that mild TBI may not result in greater parental distress or poorer family functioning than other types of injuries, except perhaps in the case of more severe injuries, such as those accompanied by LOC.

The second question aimed to better understand the influence of pre-injury and acute parental and family functioning on later PCS after mild TBI. Twelve studies assessed parental or family functioning either pre-injury or in the acute period after injury. Although the included studies varied in the domain of family functioning assessed and time post-injury, most studies reported that pre-injury or acute parental and family functioning predicted subsequent PCS in children after mild TBI (Bernard et al., 2016; Ewing-Cobbs et al., 2018; Legarreta et al., 2018; McNally et al., 2013; Morgan et al., 2015; Olsson et al., 2013; Teel et al., 2022; Truss et al., 2020; Yeates et al., 2012; Yumul et al., 2020). Four of the included studies, three of which examined parental anxiety, reported that some aspects of parental and family functioning did not predict later PCS (Bernard et al., 2020; Olsson et al., 2013; Teel et al., 2022; Zemek et al., 2013).

The third question aimed to clarify whether early PCS predicts later parental and family functioning. In other words, if acute parental and family functioning predict later PCS, does the reverse also hold, suggesting a bidirectional relationship between PCS and parental and family functioning? Two studies included in the review assessed the association of early PCS with later parental and family functioning after mild TBI. The two included studies reported that early PCS may predict later parental and family functioning, but the findings were mixed in terms of whether greater PCS predict more positive or negative family outcomes (Ganesalingam et al., 2008; Lalonde et al., 2020).

Collectively, the studies included for review in Study 1 suggest that mild TBI may not result in greater parental distress or poorer family functioning than other types of injuries (Chadwick et al., 2023). Pre-injury or acute parental and family functioning appears to predict subsequent PCS after mild TBI, depending on the specific family characteristic studied. Early PCS may also predict subsequent parental and family functioning, although findings were mixed in terms of predicting more positive or negative family outcomes. The available evidence suggests that parental and family functioning may have an important, perhaps bidirectional, association with PCS after pediatric mild TBI. However, further research is needed to provide a more thorough understanding of this association (Chadwick et al., 2023).

Overall, Study 1 highlighted the paucity of studies investigating each question of interest and the heterogeneity among the included studies, which varied in study design, sample size, participant demographics, mild TBI definition, predictor and outcome measures, and assessment time points. Most of the included studies also did not include a comparison group. These observations informed the development of Study 2, which was an original research study that aimed to identify different trajectories of child- and parent-reported PCS after mild TBI in 8- to 16-year-old children and to examine their association with parental and family functioning across the first 6-months post-injury, as compared to children with OI. Study 2 employed a large sample of children with mild TBI and OI (N = 767), drawing on data from a larger parent study examining outcomes after pediatric mild TBI in participants recruited from EDs across five Canadian pediatric research sites (A-CAP; Yeates et al., 2017).

Study 2 involved the development of three multi-trajectory models. The first model represented trajectories of child- and parent-reported cognitive and somatic PCS after mild TBI and OI. The preferred model included five trajectories: Trajectory 1 ("low acute/resolved"), which constituted 22.7% (mild TBI n = 90, OI n = 86) of the sample; Trajectory 2 ("low acute/declining"; 20.0%; mild TBI n = 86, OI n = 66); Trajectory 3 ("moderate acute/declining"; 21.9%; mild TBI n = 123, OI n = 44); Trajectory 4 ("moderate acute/persisting"; 22.0%; mild TBI n = 115, OI n = 56); and Trajectory 5 ("high acute/persisting"; 13.3%; mild TBI n = 92, OI n = 9). Several demographic and injury variables predicted the probability of trajectory membership. Injury group was significantly associated with trajectory membership, such that being in the mild TBI group increased the likelihood of being assigned to Trajectories 3, 4, or 5, all of which are characterized by trajectories of moderate or high PCS. Retrospective cognitive PCS were significantly associated with trajectory membership, such that higher levels of pre-injury symptoms increased the likelihood of being assigned to Trajectories 2, 3, 4, or 5, all of which are characterized by PCS trajectories that do not resolve over time. Sex and retrospective somatic PCS were also significantly associated with membership in Trajectory 5, such that girls and children with higher levels of pre-injury somatic symptoms were more likely to experience a trajectory of high acute/persisting PCS.

The second model represented trajectories of child- and parent-reported cognitive and somatic PCS after mild TBI. The preferred model included six trajectories: Trajectory 1 ("low acute/resolved"), which constituted 20.2% (*n* = 99) of the mild TBI sample; Trajectory 2 ("low acute/declining"; 13.3%; *n* = 62); Trajectory 3 ("moderate acute/elevated cognitive"; 20.7%; *n* = 102); Trajectory 4 ("moderate acute/declining"; 22.2%; *n* = 107); Trajectory 5 ("high acute/declining"; 17.5%; *n* = 86); and Trajectory 6 ("high acute/persisting"; 6.2%; *n* = 29). Several demographic and parental and family functioning variables predicted the probability of trajectory membership. Notably, parental social support was significantly associated with group membership, such that lower scores, which reflect less parental support, increased the likelihood of being assigned to Trajectories 3, 4, 5, or 6, all of which are characterized by trajectories of moderate or high PCS. Parental psychological functioning was significantly associated with trajectory membership, such that higher scores, which indicate more retrospective psychological distress, increased the likelihood of being assigned to Trajectory 3, the "moderate acute/elevated cognitive" trajectory. Finally, parental protectiveness was also associated with trajectory membership, such that higher scores, which reflect more protectiveness, increased the likelihood of being assigned to Trajectory 6, the “high acute/persisting” trajectory.

The third model represented trajectories of child- and parent-reported cognitive and somatic PCS after OI. The preferred model included five trajectories: Trajectory 1 (“low acute/resolved”), which constituted 31.1% (n = 79) of the OI sample; Trajectory 2 (“low acute/declining”; 21.4%; n = 54); Trajectory 3 (“low acute/persisting”; 26.0%; n = 65); Trajectory 4 (“moderate acute/persisting”; 16.3%; n = 41); and Trajectory 5 (“high acute/persisting”; 5.1%; n = 13). Notably, parental social support was significantly associated with trajectory membership, such that lower scores, which reflect less parental support, increased the likelihood of being assigned to Trajectory 5.

Overall, Study 2 identified distinct trajectories of PCS in children after mild TBI and OI and delineated the nature of predictors of these distinct trajectories. Specifically, children with mild TBI tend to display trajectories characterized by significantly more severe and longer-lasting PCS compared to children with OI. We also found that certain parental and family factors predict PCS trajectories, such that better parental and family functioning was associated with a more rapid recovery for both children with mild TBI and those with OI. This study demonstrated that demographic and family factors play an important role in predicting PCS trajectories after mild TBI. The findings from both Study 1 and Study 2 served to recognize the importance of parental and family functioning in relation to PCS after mild TBI, although future research is needed to deepen and extend these findings in order to better understanding potential implications for assessment and management of children after mild TBI.

Clinical Implications

Together, the findings from these studies underscore the importance of family characteristics in PCS recovery and can help inform clinical practice guidelines for the assessment and management of children at risk for poor recovery after mild TBI. Study 1 summarized the available evidence suggesting that parental and family functioning may have an important, perhaps bidirectional, association with PCS after pediatric mild TBI. Most studies included in the review reported that pre-injury or acute parental and family functioning predicted subsequent PCS in children after mild TBI. These findings are important clinically because many of the parent and family factors investigated are considered noninjury-related factors, which may be modifiable pre- or post-injury. Study 2 further delineated the nature of the influence of parental and family functioning on PCS after mild TBI by identifying significant predictors of PCS trajectory membership, including parental adjustment, protectiveness, and social support. These findings provide further support suggesting that clinicians should consider assessing noninjury-related factors and intervening to alter them. For example, children who are deemed to lack adequate parental support, or whose parents are not functioning optimally, may be at higher risk for poor outcomes, warranting an increased level of care post-injury. Additionally, parental adjustment, protectiveness, and social support, but not global family functioning, may be promising targets for the development of family-based interventions that seek to foster parents' adjustment, temper their protectiveness, and increase the social support they provide to their children. Existing interventions that have been validated in pediatric moderate-to-severe TBI populations, such as family problem-solving therapy, might be appropriate for application to children who sustain mild TBI and their families. Family problem-solving therapy typically involves 7-10 sessions during which the child with TBI, their parents and/or caregivers, and siblings when available learn skills in cognitive reframing, problem-solving, communication skills, and behaviour management. Several supplemental sessions are also available to address specific issues, such as pain or sleep. Family problem-solving therapy involves a combination of self-guided modules and sessions with a therapist (Wade et al., 2018), and has been shown to improve a variety of child and parent/family outcomes after TBI (Wade et al., 2018; Wade et al., 2019a; Wade et al., 2019b). With mild TBI accounting for the majority of all TBI-related ED visits (CDC, 2014), the importance of identifying symptom recovery trajectories and factors than can be targeted for intervention after mild TBI can not be understated.

Future Directions

Study 1 identified a potential bi-directional association between parental and family functioning and PCS after mild TBI and Study 2 examined the influence of pre-morbid parental and family functioning on children's PCS recovery. Although the reported findings are promising, they need replication and further investigation. Multiple directions for future work to better understand the influence of the family environment on recovery after pediatric mild TBI follow from the findings of this dissertation. Notably, Study 1 highlights the need for further prospective, longitudinal studies with appropriate comparison groups. Although Study 2 addressed this limitation by employing the largest sample size of mild TBI and OI controls to date, more studies are needed to deepen our understanding of children's PCS recovery over time. Future research may benefit from inclusion of typically developing controls in addition to OI controls, to deepen our understanding of differences related to injuries in general, as well as mild TBI specifically. Future studies may also include more comprehensive, standardized assessment of parental and family factors, such as those identified as important in Study 1 but that require a more definitive understanding of their role in recovery, including parental stress and anxiety. Such work will help to develop a more complete understanding of risk and resiliency factors following pediatric mild TBI. Another area of particular importance is to increase our understanding of how family factors may vary post-injury and how any changes may affect children's recovery course. Future studies should consider repeated and ongoing assessment of parent and family factors over time.

It will also be important for future work to inform clinical practice guidelines for the assessment and management of children at risk for poor recovery after mild TBI. Identification of different symptom trajectories and the influence of parental and family functioning as predictors of those trajectories provides guidance for clinicians in developing family-based treatments and enabling the targeting of those treatments to children at risk for poor recovery. Specifically, the findings from this dissertation suggest that interventions focused on parental protectiveness, psychological adjustment, or social support, but not global family functioning, could be particularly beneficial for improving outcomes and warrant further investigation and development. However, clinical trials are needed to provide further support for this assertion.

Future work may also involve developing a better understanding of the predictive utility of group-based multi-trajectory modeling for diagnosis and prognosis immediately after mild TBI. While group-based trajectory modeling has seen increasing adoption in clinical research, to the best of our knowledge, this is the first study to jointly model multiple symptom outcomes and to examine parental and family functioning as predictors of those outcomes after mild TBI. This detailed examination of multiple outcomes provides a fuller picture of children's symptom trajectories over time. Given our results, we believe that group-based multi-trajectory modeling could be used as a tool to more clearly identify factors that put children at greater risk for poor recovery. However, more research is needed to better understand the utility of group-based multi-trajectory modeling for clinical applications after mild TBI.

References

Abidin, R. R. (2012). *Parenting Stress Index, Fourth Edition (PSI-4).* Psychological Assessment Resources.

Achenbach, T. M., & Rescorla, L. A. (2001). *Manual for the ASEBA School-age Forms and Profiles.* University of Vermont, Research Centre for Children, Youth, and Families.

Aksan, N., Kochanska, G., & Ortmann, M. R. (2006). Mutually responsive orientation between parents and their young children: Toward methodological advances in the science of relationships. *Developmental Psychology, 42*(1), 833-848. 10.1037/0012-1649.42.5.833.

Altemus, M., Sarvaiya, N., & Epperson, C. N. (2014). Sex differences in anxiety and depression clinical perspectives. *Frontiers in Neuroendocrinology, 35*(3)*,* 320-330. 10.1016/j.yfrne.2014.05.004

American Association for Automotive Medicine. (1990). *The Abbreviated Injury Scale (AIS)-1990 Revision.* American Association for Automotive Medicine.

Anderson, V., Beauchamp, M. H., Yeates, K. O., Crossley, L., Hearps, S. J., & Catroppa, C. (2013). Social competence at 6 months following childhood traumatic brain injury. *Journal of International Neuropsychological Society, 19*(5), 539–550. 10.1017/S1355617712001543

Andruff, H., Carraro, N., Thompson, A., Gaudreau, P., & Louvet, B. (2009). Latent class growth modelling: a tutorial. *Tutorials in Quantitative Methods for Psychology, 5*(1), 11–24. 10.20982/tqmp.05.1.p011

Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19-32. 10.1080/1364557032000119616

Arrandale, V., Koehoorn, M., MacNab, Y., & Kennedy, S. M. (2006). How to use SAS Proc Traj and SAS Proc Glimmix in respiratory epidemiology. *UBC Faculty Research Publications,* 1–18.

Ayr, L. K., Yeates, K. O., Taylor, H. G., & Browne, M. (2009). Dimensions of postconcussive symptoms in children with mild traumatic brain injuries. *Journal of the International Neuropsychological Society, 15*(1), 19–30. 10.1017/S1355617708090188

Babikian, T., & Asarnow, R. (2009). Neurocognitive outcomes and recovery after pediatric TBI: Meta-analytic review of the literature. *Neuropsychology, 23*(3), 283-296. 10.1037/a0015268

Barlow, K. M. (2016). Postconcussion syndrome: A review. *Journal of Child Neurology, 31*(1), 57-67. 10.1177/0883073814543305

Barlow, K. M., Crawford, S., Stevenson, A., Sandhu, S. S., Belanger, F., & Dewey, D. (2010). Epidemiology of postconcussion syndrome in pediatric mild traumatic brain injury. *Pediatrics, 126*(2), 374-381. 10.1542/peds.2009-0925

Beauchamp, M. H., Seguin, M., Gagner, C., Lalonde, G., & Bernier, A. (2021). The PARENT model: a pathway approach for understanding parents' role after early childhood mild traumatic brain injury. *The Clinical Neuropsychologist, 35*(5), 846-867. 10.1080/13854046.2020.1834621

Bernard, C. O., McKinlay, A., Krieser, D., & Ponsford, J. L. (2020). Postconcussive symptoms following mild TBI and extracranial injury: What are the contributing factors? *Journal of the International Neuropsychological Society, 26*(5), 451-463. 10.1017/S1355617719001279.

Bernard, C. O., Ponsford, J. L., McKinlay, A., McKenzie, D., & Krieser, D. (2016). Predictors of post-concussive symptoms in young children: Injury versus non-injury related factors. *Journal of the International Neuropsychological Society, 22*(8), 793-803. 10.1017/S1355617716000709.

Bialy, L., Plint, A., Zemek, R., Johnson, D., Klassen, T., Osmond, M., Freedman, S. B., & Pediatric Emergency Research Canada (PERC) (2018). Pediatric Emergency Research Canada: Origins and evolution. *Pediatric Emergency Care*, *34*, 138–144. https://doi.org/10.1097/PEC.0000000000001360

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist, 32*(7), 513-531. 10.1037/0003-066X.32.7.513

Bryan, M. A., Rowhani-Rahbar, A., Comstock, R. D., Rivara, F., & Seattle Sports Concussion Research Collaborative. (2016). Sports- and recreation-related concussions in US youth. *Pediatrics, 138*(1), 1-1. 10.1542/peds.2015-4635

Burgess, E. S., Drotar, D., Taylor, H. G., Wade, S., Stancin, T., & Yeates, K. O. (1999). The Family Burden of Injury Interview (FBII): Reliability and validity studies. *Journal of Head Trauma Rehabilitation, 14*(4), 394-405. 10.1097/00001199-199908000-00008.

Byles, J., Byrne, C., Boyle, M. H., & Offord, D. R. (1988). Ontario child health study: reliability and validity of the general functioning scale of the McMaster family assessment device. *Family Process, 27*(1), 97-104. 10.1111/j.1545-5300.1988.00097.x

Carlozzi, N. E., Tulsky, D. S., Kail, R. V., & Beaumont, J. L. (2013). VI. NIH Toolbox Cognition Battery (CB): Measuring processing speed. *Monographs of the Society for Research in Child Development, 78*(4), 88–102. 10.1111/mono.12036

Carroll, L. J., Cassidy, J. D., Holm, L., Kraus, J., Coronado, V. G., & WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. (2004). Methodological issues and research recommendations for mild traumatic brain injury: the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *Journal of Rehabilitation Medicine,* (43 Suppl), 113–125. 10.1080/16501960410023877

Cassidy, J. D., Carroll, L. J., Peloso, P. M., Borg, J., von Holst, H., Holm, L., Kraus, J., & Coronado, V. G. (2004). Incidence, risk factors and prevention of mild traumatic brain injury: Results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *Journal of Rehabilitation Medicine, 36*(Suppl 43), 28-60. 10.1080/16501960410023732

Centers for Disease Control and Prevention. (2019). Surveillance report of traumatic brain injury-related emergency department visits, hospitalizations, and deaths – United States, 2014. *U.S. Department of Health and Human Services.*

Chadwick, L. (2020). *Injury setting and social support as moderators of the effects of pediatric concussion on post-concussive symptoms* [Master's thesis, University of Calgary]. PRISM. http://dx.doi.org/10.11575/PRISM/38214

Chadwick, L., Marbil, M., Madigan, S., Callahan, B., & Yeates, K. O. (2023). The relation between parental and family functioning and post-concussive symptoms after pediatric mild traumatic brain injury: A scoping review. *Journal of Neurotrauma, 41*(3-4), 305-318. 10.1089/neu.2023.0201. 10.1089/neu.2023.0201

Chadwick, L., Sharma, M. J., Madigan, S., Callahan, B. L., & Yeates, K. O. (2022). Classification criteria and rates of persistent postconcussive symptoms in children: A systematic review and meta-analysis. *The Journal of Pediatrics, 246,* 131-137. 10.1016/j.jpeds.2022.03.039

Chrisman, S. P., Rivara, F. P., Schiff, M. A., Zhou, C., & Comstock, R. D. (2013). Risk factors for concussive symptoms 1 week or longer in high school athletes. *Brain Injury, 27*(1), 1-9. 10.3109/02699052.2012.722251

Claar, R. L., Guite, J. W., Kaczynski, K. J., & Logan, D. E. (2010). Factor structure of the Adult Responses to Children's Symptoms: Validation in children and adolescents with diverse chronic pain conditions. *The Clinical Journal of Pain, 26*(5), 410-417. 10.1097/AJP.0b013e3181cf5706

Claar, R. L., Simons, L. E., & Logan, D. E. (2008). Parental response to children's pain: The moderating impact of children's emotional distress on symptoms and disability. *Pain, 138*(1), 172-179. 10.1016/j.pain.2007.12.005

Cobb, S. (1976). Social support as a moderator of life stress. *Psychosomatic Medicine, 38*(5), 300-314. https://doi.org/10.1097/00006842-197609000-00003

Covassin, T., Crutcher, B., Bleecker, A., Heiden, E. O., Dailey, A., & Yang, J. (2014). Postinjury anxiety and social support among collegiate athletes: A comparison between orthopaedic injuries and concussions. *Journal of Athletic Training, 49*(4), 462-468. 10.4085/1062-6059-49.2.03

Cutrona, C. E., & Suhr, J. A. (1992). Controllability of stressful events and satisfaction with spouse support behaviors. *Communication Research, 19*(2), 154-174. 10.1177/009365092019002002

Davis, G. A., Echemendia, R. J., Ahmed, O. H., Anderson, V., Blauwet, C., Brett, B. L., … Zemek, R. (2023). Introducing the Child Sport Concussion Assessment Tool 6 (Child

SCAT6). *British Journal of Sports Medicine, 57*(11), 632-635. 10.1136/bjsports-2023-106853

Derogatis, L., & Melisaratos, N. (1983). The Brief Symptom Inventory: an introductory report. *Psychological Medicine, 13*(3), 595-605. 10.1017/S0033291700048017

Drapeau, A., Beaulieu-Prevost, D., Marchand, A., Boyer, R., Preville, M., & Kairouz, S. (2010). A life-course and time perspective on the construct validity of psychological distress in women and men: Measurement invariance of the K6 across gender. *BMC Medical Research Methodology, 10*(1), 68. 10.1186/1471-2288-10-68

Driscoll, K., & Pianta, R. C. (2011). Mothers' and fathers' perceptions of conflict and closeness in parent-child relationships during early childhood. *Journal of Early Childhood and Infant Psychology, 7*(1), 1-24.

Dunne, L., Perich, T., & Meade, T. (2019). The relationship between social support and personal recovery in bipolar disorder. *Psychiatric Rehabilitation Journal, 42*(1), 100-103. 10.1037/prj0000319

Edmed, S., & Sullivan, K. (2012). Depression, anxiety, and stress as predictors of postconcussion-like symptoms in a non-clinical sample. *Psychiatry Research, 200*(1), 41-45. 10.1016/j.psychres.2012.05.022.

Emiroglu, F. N. I., Kurul, S., Akay, A., Miral, S., & Dirik, E. (2004). Assessment of child neurology outpatients with headache, dizziness, and fainting. *Journal of Child Neurology, 19*(5), 332-336. 10.1177/088307380401900505.

Engel, G. L. (1977). The need for a new medical model: A challenge for biomedicine. *Science, 196*(4286), 129-136. 10.1126/science.847460

Ewing-Cobbs, L., Cox, C. S., Clark, A. E., Holubkov, R., & Keenan, H. T. (2018). Persistent postconcussion symptoms after injury. *Pediatrics, 142*(5), e20180939. 10.1542/peds.2018-0939.

Fay, T. B., Yeates, K. O., Taylor, H. G. , Bangert, B., Dietrich, A., Nuss, K. E., Rusin, J., & Wright, M. (2010). Cognitive reserve as a moderator of postconcussive symptoms in children with complicated and uncomplicated mild traumatic brain injury. *Journal of the International Neuropsychological Society, 16*(1), 94–105. 10.1017/S1355617709991007

Feldman, J. M., Ortega, A. N., Koinis-Mitchell, D., Kuo, A. A., & Canino, G. (2010). Child and family psychiatric and psychological factors associated with child physical health problems: Results from the Boricua youth study. *Journal of Nervous and Mental Disorders, 198*(4), 272-279. 10.1097/NMD.0b013e3181d61271.

Franklin, J. M., Shrank, W. H., Pakes, J., Sanfelix-Gimeno, G., Matlin, O. S., Brennan, T. A., & Choudhry, N. K. (2013). Group-based trajectory models: A new approach to classifying and predicting long-term medication adherence. *Medical Care, 51*(9), 789-796. 10.1097/MLR.0b013e3182984c1f

Furukawa, T. A., Kawakami, N., Saitoh, M., Ono, Y., Nakane, Y., Nakamura, Y., Tachimori, H., Iwata, N., Uda, H., Nakane, H., Watanabe, M., Naganuma, Y., Hata, Y., Kobayashi, M., Miyake, Y., Takeshima, T., & Kikkawa, T. (2008). The performance of the Japanese version of the K6 and K10 in the World Mental Health Survey Japan. *International Journal of Methods in Psychiatric Research, 17*(3),152-158. 10.1002/mpr.257

Furukawa, T. A., Kessler, R. C., Slade, T., & Andrews, G. (2003). The performance of the K6 and K10 screening scales for psychological distress in the Australian National Survey of

Mental Health and Well-Being. *Psychological Medicine, 33*(2), 357-362. 10.1017/S0033291702006700

Ganesalingam, K., Yeates, K. O., Ginn, M. S., Taylor, H. G., Dietrich, A., Nuss, K., & Wright, M. (2008). Family burden and parental distress following mild traumatic brain injury in children and its relationship to post-concussive symptoms. *Journal of Pediatric Psychology, 33*(6), 621-629. 10.1093/jpepsy/jsm133.

Gioia, G., Collins, M., & Isquith, P. K. (2008). Improving identification and diagnosis of mild traumatic brain injury with evidence: Psychometric support for the acute concussion evaluation. *Journal of Head Trauma Rehabilitation, 23*(4), 230-242. 10.1097/01.HTR.0000327255.38881.ca.

Goldberg, D. P., & Williams, P. (1998). *A users guide to the general health questionnaire.* National Foundation for Educational Research.

Haber, M. G., Cohen, J. L., Lucas, T., & Baltes, B. B. (2007). The relationship between self-reported received and perceived social support: A meta-analytic review. *The American Journal of Community Psychology, 39*(1-2)*,* 133-144. 10.1007/s10464-007-9100-9

Hammond, F. M., Giacino, J. T., Richardson, R. N., Sherer, M., Zafonte, R. D., Whyte, J., Arciniegas, D. B., & Tang, X. (2019). Disorders of consciousness due to traumatic brain injury: Functional status ten years post-injury. *Journal of Neurotrauma, 36*(7), 1136-1146. https://doi.org/10.1089/neu.2018.5954

Harter, S. (1985). *Manual for the Social Support Scale for Children.* University of Denver.

Haviland, A. M., Jones, B. L., & Nagin, D. S. (2011). Group-based trajectory modeling extended to account for nonrandom participant attrition. *Sociological Methods & Research, 40*(2), 367–390. 10.1177/0049124111400041

Hogan, B. E., Linden, W., & Najarian, B. (2002). Social support interventions: Do they work? *Clinical Psychology Review, 22*(3), 381-440. 10.1016/S0272-7358(01)00102-77

Jones, B. L., & Nagin, D. S. (2013). A note on a Stata plugin for estimating group-based trajectory models. *Sociological Methods & Research, 42*(4), 608-613. 10.1177/0049124113503141

Kabacoff, R. I., Miller, I. W., Bishop, D. S., Epstein, N. B, & Keitner, G. I. (1990). A psychometric study of the McMaster Family Assessment Device in psychiatric, medical, and nonclinical samples. *Journal of Family Psychology, 3*(4), 431-439, 10.1037/0893-3200.3.4.431

Kessler, R. C., Andrews, G., Colpe, L. J., Hiripi, E., Mroczek, D. K., Normand, S.-L. T., Walters, E. E., & Zaslavsky, A. M. (2002). Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychological Medicine, 32*(6), 959-976. 10.1017/S0033291702006074.

Kessler, R. C., Barker, P. R., Colpe, L. J., Epstein, J. F., Gfroerer, J. C., Hiripi, E., Howes, M. J., Normand, S. T., Manderscheid, R. W., Walters, E. E., & Zaslavsky, A. M. (2003). Screening for serious mental illness in the general population. *Archives of General Psychiatry, 60*(2), 184–189. 10.1001/archpsyc.60.2.184

Kessler, R. C., Green, J. G., Gruber, M. J., Sampson, N. A., Bromet, E., Cuitan, M., Furukawa, T. A., Gureje, O., Hinkov, H., Hu, C., Lara, C., Lee, S., Mneimneh, Z., Myer, L., Oakley-Browne, M., Posada-Villa, J., Sagar, R., Viana, M. C., & Zaslavsky, A. M. (2010). Screening for serious mental illness in the general population with the K6 screening scale: results from the WHO World Mental Health (WMH) survey initiative. *International Journal of Methods in Psychiatric Research, 19*(Suppl 1), 4–22. 10.1002/mpr.333

Kita, H., Mallory, K. D., Hickling, A., Wilson, K. E., Kroshus, E., & Reed, N. (2020). Social support during youth concussion recovery. *Brain Injury, 34*(6), 782-790. 10.1080/02699052.2020.1753243

King, N. S., Crawford, S., Wenden, F. J., Moss, N. E. G., & Wade, D. T. (1995). The Rivermead Postconcussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. *Journal of Neurology, 242*(9), 587-592. 10.1007/bf00868811.

Kochanska, G., Aksan, N., Prisco, T. R., & Adams, E. E. (2008). Mother-child and father-child mutually responsive orientation in the first 2 years and children's outcomes at preschool age: Mechanisms of influence. *Child Development, 79*(1), 30-44. 10.1111/j.1467-8624.2007.01109.x.

Lalonde, G. Bernier, A., Beaudoin, C., Gravel, J., & Beauchamp, M. (2020). Factors contributing to parent-child interaction quality following mild traumatic brain injury in early childhood. *Journal of Neuropsychology, 14*(1), 98-120. 10.1111/jnp.12179

Lee, E.-H. (2012). Review of the psychometric evidence of the perceived stress scale. *Asian Nursing Research, 6*(4), 121-127. 10.1016/j.anr.2012.08.004.

Legarreta, A. D., Brett, B. L., Solomon, G. S., & Zuckerman, S. L. (2018). The role of family and personal psychiatric history in postconcussion syndrome following sport-related concussion: a story of compounding risk. *Journal of Neurosurgery Pediatrics, 22*(3), 238-243. 10.3171/2018.3.PEDS1850.

Lloyd, J., Wilson, M. L., Tenovuo, O., & Saarijarvi, S. (2014). Outcomes from mild and moderate traumatic brain injuries among children and adolescents: A systematic review of studies from 2008-2013. *Brain Injury, 29*(5), 539-549. 10.3109/02699052.2014.1002003

Lore, H., Nguefack, N., Page, M. G., Katz, J., Choiniere, M., Vanasse, A., Dorias, M., Samb, O. M., & Lacasse, A. (2020). Trajectory modelling techniques useful to epidemiological research: A comparative narrative review of approaches. *Clinical Epidemiology, 12,* 1205-1222. 10.2147/CLEP.S265287

Loughran, T., & Nagin, D. S. (2023). Modeling developmental trajectories: A group-based approach [Lecture materials].

Lovell, M. R., Iverson, G. L., Collins, M. W., Podell, K., Johnston, K. M., Pardini, D., Pardini, J., Norwig, J., & Maroon, J. C. (2006). Measurement of symptoms following sports-related concussion: Reliability and normative data for the post-concussion scale. *Applied Neuropsychology, 13*(3), 166-174. 10.1207/s15324826an1303_4.

Lowery Wilson, M., Tenovuo, O., Gissler, M., & Saarijarvi, S. (2019). Association between parent mental health and paediatric TBI: epidemiological observations from the 1987 Finnish Birth Cohort. *Injury Prevention, 25*(4), 283-289. 10.1136/injuryprev-2017-042624

Luis, C. A., Vanderploeg, R. D., & Curtiss, G. (2003). Predictors of post-concussion symptom complex in community dwelling male veterans. *Journal of the International Neuropsychological Society, 9*(7), 1001-1015. 10.1017/S1355617703970044

Lumba-Brown, A., Yeates, K. O., Sarmiento, K., Breiding, M. J., Haegerich, T. M., Gioia, G. A., Turner, M., Benzel, E. C., Suskauer, S., J., Giza, C. C., Joseph, M., Broomand, C., Weissman, B., Weissman, B., Gordon, W., Wright, D. W., Moser, R. S., McAvoy, K., Ewing-Cobbs, L., … Timmons, S. D. (2018). Centers for Disease Control and Prevention Guidelne on the diagnosis and management of mild traumatic brain injury among children. *JAMA Pediatrics, 172*(11), e182853. 10.1001/jamapediatrics.2018.2853

Malecki, C. K., Demaray, M. K., & Elliot, S. N. (2014). *A Working manual for the Development of the Child and Adolescent Social Support Scale (2000).*

Malecki, C. K., & Demaray, M. K. (2002). Measuring perceived social support: development of the child and adolescent social support scale (CASSS). *Psychology in the Schools, 39*(1), 1-18. 10.1002/pits.10004 25.

McCarty, C. A., Zatzick, D. F., Marcynyszyn, L. A., Wang, J., Hilt, R., Jinguji, T., Quitiquit, C., Chrisman, S. P. D., & Rivara, F. P. (2021). Effect of collaborative care on persistent postconcussive symptoms in adolescents: A randomized clinical trial. *JAMA Network Open, 4*(2), e210207. 10.1001/jamanetworkopen.2021.0207

McCauley, S. R., Wilde, E. A., Anderson, V. A., Bedell, G., Beers, S. R., Campbell, T. F., Chapman, S. B., Ewing-Cobbs, L., Gerring, J. P., Gioia, G. A., Levin, H. S., Michaud, L. J., Prasad, M. R., Swaine, B. R., Turkstra, L. S., Wade, S. L., & Yeates, K. O. (2012). Recommendations for the use of common outcome measures in pediatric traumatic brain injury research. *Journal of Neurotrauma, 29*(4), 678-705. 10.1089/neu.2011.1838

McCrea, M., Hammeke, T., Olsen, G., Leo, P., & Guskiewicz, K. (2004). Unreported concussion in high school football players: Implications for prevention. *Clinical Journal of Sport Medicine, 14*(1), 13-17. 10.1097/00042752-200401000-00003

McNally, K. A., Dietrich, A., Nuss, K., Wright, M., Taylor, H. G., Bangert, B., Rusin, J., & Yeates, K. O. (2013). Injury versus noninjury factors as predictors of postconcussive symptoms following mild traumatic brain injury in children. *Neuropsychology, 27*(1), 1-12. 10.1037/a0031370

Meares, S., Shores, E. A., Taylor, A. J., Batchelor, J., Bryant, R. A., Baguley, I. J., Chapman, J., Gurka, J., Dawson, K., Capon, L., & Marosszeky, J. E. (2008). Mild traumatic brain injury does not predict acute postconcussion syndrome. *Journal of Neurology, Neurosurgery, and Psychiatry, 79*(3), 300-306. 10.1136/jnnp.2007.126565

Menon, D. K., Schwab, K., Wright, D. W., Maas, A. I., Demographics and Clinical Assessment Working Group of the International and Interagency Initiative toward Common Data Elements for Research on Traumatic Brain Injury and Psychological Health. (2010). Position statement: Definition of traumatic brain injury. *Archives of Physical Medicine and Rehabilitation, 91*(11), 1637-1640. 10.1016/j.apmr.2010.05.017

Micklewright, J. L., King, T. Z., O'Toole, K., Henrich, C., & Floyd, F. J. (2012). Parental distress, parenting practices, and child adaptive outcomes following traumatic brain injury. *Journal of the International Neuropsychological Society, 18*(2), 343-350. 10.1017/S1355617711001792

Miller, E. W., Epstein, N. B., Bishop, D. S., & Keitner, G. I. (1985). The McMaster Family Assessment Device: Reliability and validity. *Journal of Marital and Family Therapy, 11*(4), 345-356. 10.1111/j.1752-0606.1985.tb00028.x

Mitchell, C. M., & Beals, J. (2011). The utility of the Kessler Screening Scale for Psychological Distress (K6) in two American Indian communities. *Psychological Assessment, 23*(3), 752-761. 10.1037/a0023288

Mittenberg, W., Wittner, M. S., & Miller, L. J. (1997). Postconcussion syndrome occurs in children. *Neuropsychology, 11*(3), 447-452. 10.1037/0894-4105.11.3.447

Moos, R. H., & Moos, B. S. (1994). *Life Stressors and Social Resources Inventory: Adult form manual.* Psychological Assessment Resources.

Moos, R. H., & Moos, B. S. (1988). *Life Stressors and Social Resources Inventory: Preliminary manual.* Stanford University Medical Center.

Morgan, C. D., Zuckerman, S. L., Lee, Y. M., King, L., Beaird, S., Sills, A. K., & Solomon, G. S. (2015). Predictors of postconcussion syndrome after sports-related concussion in young athletes: a matched case-control study. *Journal of Neurosurgery: Pediatrics, 15*(6), 589-598. 10.3171/2014.10.PEDS14356

Moran, L. M., Taylor, H. G., Rusin, J., Bangert, B., Dietrich, A., Nuss, K. E., Wright, M., Minich, N., & Yeates, K. O. (2012). Quality of life in pediatric mild traumatic brain injury and its relationship to postconcussive symptoms. *Journal of Pediatric Psychology, 37*(7), 736-744. 10.1093/jpepsy/jsr087

Moran, L. M., Taylor, H. G., Rusin, J., Bangert, B., Dietrich, A., Nuss, K. E., Wright, M., & Yeates, K. O. (2011). Do postconcussive symptoms discriminate injury severity in pediatric mild traumatic brain injury? *Journal of Head Trauma Rehabilitation, 26*(5), 348-354. 10.1097/HTR.0b013e3181f8d32e

Nagin, D. S. (2005). *Group-based modeling of development.* Harvard University Press.

Nagin, D. S., Jones, B. L., Passos, V. L., & Tremblay, R. E. (2018). Group-based multi-trajectory modeling. *Statistical Methods in Medical Research, 27*(7), 2015-2023. 10.1177/0962280216673085

Nagin, D. S., & Odgers, C. L. (2010). Group-based trajectory modeling in clinical research. *Annual Review of Clinical Psychology, 6*(1), 109-138. 10.1146/annurev.clinpsy.121208.131413

Noel, M., Alberts, N., Langer, S. L., Levy, R. L., Walker, L. S., & Palermo, T. M. (2016). The sensitivity to change and responsiveness of the Adult Responses to Children's Symptoms in Children and Adolescents with chronic pain. *Journal of Pediatric Psychology, 41*(3), 350-362. 10.1093/jpepsy/jsv095

Noel, M., Palermo, T. M., Essner, B., Zhou, C., Levy, R. L., Langer, S. L., Sherman, A. L., & Walker, L. S. (2015). A developmental analysis of the factorial validity of the parent-report version of the adult responses to Children's Symptoms in children versus adolescents with chronic pain or pain-related chronic illness. *Journal of Pain, 16*(1), 31–41. 10.1016/j.jpain.2014.10.005

Olsson, K. A., Lloyd, O. T., LeBrocque, R. M., McKinlay, L., Anderson, V. A., & Kenardy, J. A. (2013). Predictors of child post-concussion symptoms at 6 and 18 months following mild traumatic brain injury. *Brain Injury, 27*(2), 145-157. 10.3109/02699052.2012.729286

Pediatric Emergency Research Canada. (2019). Retrieved from https://perc-canada.ca/

Ponsford, J., Willmont, C., Rothwell, A., Cameron, P., Ayton, G., Nelms, R., Curran, C., & Ng, K. T. (1999). Cognitive and behavioral outcome following mild traumatic head injury in children. *The Journal of Head Trauma Rehabilitation, 14*(4), 360–372. 10.1097/00001199-199908000-00005

Prochaska, J. J., Sung, H., Max, W., Shi, Y., & Ong, M. (2012). Validity study of the K6 scale as a measure of moderate mental distress based on mental health treatment need and utilization. *International Journal of Methods in Psychiatric Research, 21*(2), 88-97. 10.1002/mpr.1349

Raj, S. P., Wade, S. L., Cassedy, A., Taylor, H. G., Stancin, T., Brown, T. M., & Kirkwood, M. W. (2014). Parent psychological functioning and communication predict externalizing behavior problems after pediatric traumatic brain injury. *Journal of Pediatric Psychology, 39*(1), 84-95. 10.1093/jpepsy/jst075

Ram, N., & Grimm, K. J. (2009). Growth mixture modeling: a method for identifying differences in longitudinal change among unobserved groups. *International Journal of Behavioral Development, 33*(6), 565–576. 10.1177/ 0165025409343765

Rashid, M., Goez, H. R., Mabood, N., Damanhoury, S., Yager, J. Y., Joyce, A. S., & Newton, A. S. (2014). The impact of pediatric traumatic brain injury (TBI) on family functioning: A systematic review. *Journal of Pediatric Rehabilitation Medicine, 7*(3), 241-254. 10.3233/PRM-140293

Ray, J. V., Sullivan, C. J., Loughran, T. A., & Jones, S. E. (2018). The impact of missing risk factor data on semiparametric group-based trajectory models. *Journal of Developmental Life-Course Criminology, 4*(3), 276–296. 10.1007/s40865-018-0085-x

Rigney, G., Jo, J., Williams, K., Terry, D. P., & Zuckerman, S. L. (2023). Parental factors associated with recovery after mild traumatic brain injury: A systematic review. *Journal of Neurotrauma, 40*(19-20), 2015-2036. 10.1089/neu.2023.0015

Rivara, J. B., Jaffe, K. M., Polissar, N. L., Fay, G. C., Liao, S., & Martin, K. M. (1996). Predictors of family functioning and change 3 years after traumatic brain injury in children. *Archives of Physical Medicine and Rehabilitation, 77*(8), 754-764. 10.1016/s0003-9993(96)90253-1

Rivara, J. B., Jaffe, K. M., Polissar, N. L., Fay, G. C., Martin, K. M., Shurtleff, H. A., & Liao, S. (1994). Family functioning and children's academic performance and behavior problems in the year following traumatic brain injury. *Archives of Physical Medicine and Rehabilitation, 75*(4), 369-379. 10.1016/0003-9993(94)90157-0

Rivara, F. P., Koepsell, T. D., Wang, J., Temkin, N., Dorsch, A., Vavilala, M. S., Durbin, D., & Jaffe, K. M. (2012). Incidence of disability among children 12 months after traumatic brain injury. *The American Journal of Public Health, 102*(11), 2074-2079. 10.1037/bul0000058

Rueger, S. Y., Malecki, C. K., & Demaray, M. K. (2010). Relationship between multiple sources of perceived social support and psychological and academic adjustment in early adolescence: Comparisons across gender. *Journal of Youth and Adolescence, 39*(1), 47-61. 10.1007/s10964-008-9368-6

Ryan, N. P., van Bijnen, L., Catroppa, C., Beauchamp, M. H., Crossley, L., Hearps, S., & Anderson, V. (2016). Longitudinal outcome and recovery of social problems after pediatric traumatic brain injury (TBI): Contribution of brain insult and family environment. *International Journal of Developmental Neuroscience, 49,* 23-30. 10.1016/j.ijdevneu.2015.12.004

Sady, M. D., Vaughan, C. G., & Gioia, G. A. (2014). Psychometric characteristics of the postconcussion symptom inventory in children and adolescents. *Archives of Clinical Neuropsychology, 29*(4), 348-363. 10.1093/arclin/acu014

Scopaz, K. A., & Hatzenbuehler, J. R. (2013). Risk modifiers for concussion and prolonged recovery. *Sports Health, 5*(6), 537-541. 10.1177/1941738112473059

Sieberg, C. B., Williams, S., & Simons, L. E. (2011). Do parent protective responses mediate the relation between parent distress and child functional disability among children with chronic pain? *Journal of Pediatric Psychology, 36*(9), 1043-1051. 10.1093/jpepsy/jst043

Snell, D. L., Martin, R., Surgenor, L. J., Siegert, R. J., & Hay-Smith, E. J. C. (2017). What's wrong with me? Seeking a coherent understanding of recovery after mild traumatic brain injury. *Disability and Rehabilitation, 39*(19), 1968-1975. 10.1080/09638288.2016.1213895

Spielberger, C. D., & Gorsuch, R. L. (1983). *State-trait anxiety inventory for adults manual and sample: Manual, instrument and scoring guide.* Mind Garden, Inc.

Taylor, H. G., Dietrich, A., Nuss, K., Wright, M., Rusin, J., Bangert, B., Minich, N., & Yeates, K. O. (2010). Post-concussive symptoms in children with mild traumatic brain injury. *Neuropsychology,24*(2), 148-159. 10.1037/a0018112

Taylor, H. G., Yeates, K. O., Wade, S. L., Drotar, D., Stancin, T., & Burant, C. (2001). Bidirectional child-family influences on outcomes of traumatic brain injury in children. *Journal of the International Neuropsychological Society, 7*(6), 755-767. 10.1017/S1355617701766118

Taylor, H. G., Yeates, K. O., Wade, S. L., Drotar, D., Stancin, T., & Minich, N. (2002). A prospective study of short- and long-term outcomes after traumatic brain injury in children: Behavior and achievement. *Neuropsychology, 16*(1), 15-27. 10.1037/0894-4105.16.1.15

Teasdale, G., & Jennet, B. (1974). Assessment of coma and impaired consciousness. A practical scale. *Lancet, 2*(7872), 81-84. 10.1016/s0140-6736(74)91639-0

Teel, E. F., Caron, J. G., & Gagnon, I. J. (2022). Higher parental stress is significantly related to longer clinical recovery times in concussed children: A mixed-methods study. *Journal of Science and Medicine in Sport, 25*(2), 108-114. 10.1016/j.jsams.2021.08.014

Trbovich, A. M., Preszler, J., Emami, K., Cohen, P., Eagle, S., Collins, M. W., & Kontos, A. P. (2022). Is overparenting associated with adolescent/young adult emotional functioning and clinical outcomes following concussion? *Child Psychiatry & Human Development, 53*(6), 1231-1239. https://doi.org/10.1007/s10578-021-01204-8

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M. G., Garritty, C., … Straus, S. E. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine, 169*(7), 467-473. 10.7326/M18-0850

Truss, K., Hearps, S. J. C., Babl, F. E., Franz, E., Takagi, M., Davis, G. A., Clarke, C., Anderson, N., Rausa, V. C., Bressan, S., Dunne, K., & Anderson, V. (2020). Trajectories and risk factors for pediatric postconcussive symptom recovery. *Neurosurgery, 88*(1), 36-45. 10.1093/neuros/nyaa310.

van de Schoot, R., Sijbrandij, M., Winter, S. D., Depaoli, S., & Vermunt, J. K. (2017). The GRoLTS-Checklist: Guidelines for reporting on latent trajectory studies. *Structural Equation Modeling: A Multidisciplinary Journal, 24*(3), 451-467. 10.1080/10705511.2016.1247646

Veritas Health Innovation (n.d.). *Covidence systematic review software* [Computer software]. https://www.covidence.org/

Wade, S. L., Cassedy, A. E., McNally, K. A., Kurowski, B. G., Kirkwood, M. W., Stancin, T., & Taylor, H. G. (2019a). A randomized comparative effectiveness trial of family-problem solving treatment for adolescent brain injury: Parent outcomes from the coping with head injury through problem-solving (CHIPS) study. *Journal of Head Trauma Rehabilitation, 34*(6), E1-E9. 10.1097/HTR.0000000000000487

Wade, S. L., Fisher, A. P., Kaizar, E. E., Yeates, K. O., Taylor, H. G., & Zhang, N. (2019b). Recovery trajectories of child and family outcomes following online family problem-solving therapy for children and adolescents after traumatic brain injury. *Journal of the International Neuropsychological Society, 25*(9), 941-949. 10.1017/S1355617719000778

Wade, S. L., Kaizar, E. E., Narad, M., Zang, H., Kurowski, B. G., Yeates, K. O., Taylor, H. G., & Zhang, N. (2018). Online family problem-solving treatment for pediatric traumatic brain injury. *Pediatrics, 142*(6), 1. 10.1542/peds.2018-0422

Ware, A. L., Shukla, A., Goodrich-Hunsaker, N. J., Lebel, C., Wilde, E. A., Abildskov, T. J., Bigler, E. D., Cohen, D. M., Mihalov, L. K., Bacevice, A., Banger, B. A., Taylor, H. G., & Yeates, K. O. (2020). Post-acute white matter microstructure predicts post-acute and chronic post-concussive symptom severity following mild traumatic brain injury in children. *NeuroImage: Clinical, 25,* 102106. 10.1016/j.nicl.2019.102106

Wood, R. L., McCabe, M., & Dawkins, J. (2011). The role of anxiety sensitivity in symptom perception after minor head injury: an exploratory study. *Brain Injury, 25*(13-14), 1296-1299. 10.3109/02699052.2011.624569

Yeates, K. O., Beauchamp, M., Craig, W., Doan, Q., Zemek, R., Bjornson, B. H., Gravel, J., Mikrogianakis, A., Goodyear, B., Abdeen, N., Beaulieu, C., Dehaes, M., Deschenes, S., Harris, A., Lebel, C., Lamont, R., Williamson, T., Barlow, K. M., Bernier, F., … Schneider, K. J. (2017). Advancing concussion assessment in pediatrics (A-CAP): a prospective, concurrent cohort, longitudinal study of mild traumatic brain injury in children: study protocol. *BMJ Open, 7*(7), e017012. 10.1136/ bmjopen-2017-017012

Yeates, K. O., Kaizar, E., Rusin, J., Bangert, B., Dietrich, A., Nuss, K., Wright, M., & Taylor, H. G. (2012). Reliable change in postconcussive symptoms and its functional consequences among children with mild traumatic brain injury. *Archives of Pediatrics & Adolescent Medicine, 166*(7), 615-622. 10.1001/archpediatrics.2011.1082

Yeates, K. O., Taylor, H. G., Rusin, J., Bangert, B., Dietrich, A., Nuss, K., Wright, M., Nagin, D. S., & Jones, B. L. (2009). Longitudinal trajectories of postconcussive symptoms in children with traumatic brain injuries and their relationship to acute clinical status. *Pediatrics, 123*(3), 735-743. 10.1542/peds.2008-1056

Yeates, K. O., Taylor, H. G., Rusin, J., Bangert, B., Dietrich, A., Nuss, K., & Wright, M. (2012). Premorbid child and family functioning as predictors of post-concussive symptoms in children with mild traumatic brain injuries. *International Journal of Developmental Neuroscience, 30*(3), 231-237. 10.1016/j.ijdevneu.2011.05.008

Yeates, K. O., Taylor, H. G., Walz, N. C., Stancin, T., Wade, S. L., & Roa, S. M. (2010). The family environment as a moderator of psychosocial outcomes following traumatic brain injury in young children. *Neuropsychology, 24*(3), 345-356. 10.1037/a0018387

Yeates, K. O., Taylor, H. G., Barry, C. T., Drotar, D., Wade, S. L., & Stancin, T. (2001). Neurobehavioral symptoms in childhood closed-head injuries: Changes in prevalence and correlates during the first year postinjury. *Journal of Pediatric Psychology, 26*(2), 79-91. 10.1093/jpepsy/26.2.79

Yeates, K. O., Luria, J., Bartkowski, H., Rusin, J., Martin, L., & Bigler, E. D. (1999). Postconcussive symptoms in children with mild closed head injuries. *Journal of Head Trauma Rehabilitation, 14*(4), 337-350. 10.1097/00001199-199908000-00003

Yeates, T. M., Taylor, H. G., Bigler, E. D., Minich, N. M., Tang, K., Cohen, D. M., Bacevice, A., Mihalov, L. K., Bangert, B., Zumberge, N. A., & Yeates, K. O. (2022). Sex differences in the outcome of mild traumatic brain injury in children presenting to the emergency department. *Journal of Neurotrauma, 39*(1-2), 93-101. 10.1089/neu.2020.7470

Yumul, J. N., McKinlay, A., Than, M., Anderson, V., & Catroppa, C. (2020). Concussive symptoms following pediatric mild traumatic brain injury. *Journal of Head Trauma Rehabilitation, 35*(4), 279-287. 10.1097/HTR.0000000000000565

Zemek, R., Barrowman, N., Freedman, S. B., Gravel, J., Gagnon, I., McGahern, C., Aglipay, M., Sangha, G., Boutis, K., Beer, D., Craig, W., Burns, E., Farion, K. J., Mikrogianakis, A., Barlow, K. M., Dubrovsky, A. S., Meeuwisse, W., Gioia, G., Meehan, W. P., & Beauchamp, M. H. (2016). Clinical risk score for persistent postconcussion symptoms among children with acute concussion in the ED. *JAMA, 315*(10), 1014-1025. 10.1001/jama.2016.1203

Zemek, R., Clarkin, C., Farion, K.J., Vassilyadi, M., Anderson, P., Irish, B., Goulet, K., Barrowman, N., Osmond, M. H., & Alpern, E. (2013). Parental anxiety at initial acute presentation is not associated with prolonged symptoms following pediatric concussion. *Academic Emergency Medicine, 20*(10), 1041-1049. 10.1111/acem.12220

Zemek, R. L., Farion, K. J., Sampson, M., & McGahern, C. (2013). Prognosticators of persistent symptoms following pediatric concussion: A systematic review. *JAMA Pediatrics, 167*(3), 1-7. 10.1001/2013.jamapediatrics.216

Zemek, R. L., Grool, A. M., Rodriquez, D. D., Dematteo, C., Benchimol, E. I., Guttmann, A., & Macpherson, A. K. (2017). Annual and seasonal trends in ambulatory visits for pediatric concussion in Ontario between 2003 and 2013. *The Journal of Pediatrics, 181,* 222-228. 10.1016/j.jpeds.2016.10.067

Zhang, C., Tang, K., Zemek, R., Beauchamp, M. H., Craig, W., Doan, Q., & Yeates, K. O. (2022). Factor structure and measurement invariance of post-concussion symptom ratings on the Health and Behaviour Inventory across time, raters, and groups: An A-CAP study. *Journal of the International Neuropsychological Society, 29*(4), 346-359. 10.1017/S1355617722000340

Appendix A: Full List of Scoping Review Search Terms

PsycINFO Ovid Search Terms

Concept 1

Exp Traumatic Brain Injury/
Craniocerebral Trauma.tw,id.
(concussion* or concussed or concussive or subconcuss* or sub-concuss*).tw,id.
(Mild adj3 (traumatic brain injur* or tbi*)).tw,id.
mtbi*.tw,id.
(Head adj2 (injur* or impact* or trauma*)).tw,id.
(Traumatic brain injur* or tbi*).tw,id.
(Neurotrauma* or neuro-trauma*).tw,id.
(Craniocerebral adj2 (trauma* or injur*)).tw,id.
Brain contus*.tw,id.

Concept 2

Exp Family Relations/
Exp Caregivers/
Exp Parents/
Family factors.tw,id.
(family or families).tw,id.
(parent* or parent-child interact* or dyad).tw,id.
(mother* or mom or moms or maternal or father* or dad or dads or paternal or brother or sister or sibling*).tw,id.

Concept 3

Exp Prognosis/
Exp Symptoms/
(recover* or prognosis or symptom* or outcome* or postconcussi* or post-concussi*).tw,id.
(return to or return-to adj2 (play* or school* or learn*)).tw,id.

Search = Concept 1 AND Concept 2 AND Concept 3
PsycINFO results = 2,302

Medline & CENTRAL Search Terms

Concept 1

Exp Brain Concussion/
Exp Brain Injuries/
(concussion* or concussed or concussive or subconcuss* or sub-concuss*).tw,kw.
(Mild adj3 (traumatic brain injur* or tbi*)).tw,kw.
mtbi*.tw,kw.
(Head adj2 (injur* or impact* or trauma*)).tw,kw.
(Traumatic brain injur* or tbi*).tw,kw.
(Neurotrauma* or neuro-trauma*).tw,kw.
(Craniocerebral adj2 (trauma* or injur*)).tw,kw.
Brain contus*.tw,kw.

Concept 2

Exp Family/
Exp Caregivers/
Exp Parents/
Family factors.tw,kw.
(family or families).tw,kw.
(parent* or parent-child interact* or dyad).tw,kw.
(mother* or mom or moms or maternal or father* or dad or dads or paternal or brother or sister or sibling*).tw,kw.

Concept 3

Exp Prognosis/
Exp Behavioral Symptoms/
(recover* or prognosis or symptom* or outcome* or postconcussi* or post-concussi*).tw,kw.
(return to or return-to adj2 (play* or school* or learn*)).tw,kw.

Search = Concept 1 AND Concept 2 AND Concept 3
Medline results = 4,402
CENTRAL results = 909

EMBASE Search Terms

Concept 1

Exp Traumatic Brain Injury/
Exp Concussion/
(concussion* or concussed or concussive or subconcuss* or sub-concuss*).tw,kw.
(Mild adj3 (traumatic brain injur* or tbi*)).tw,kw.
mtbi*.tw,kw.
(Head adj2 (injur* or impact* or trauma*)).tw,kw.
(Traumatic brain injur* or tbi*).tw,kw.
(Neurotrauma* or neuro-trauma*).tw,kw.
(Craniocerebral adj2 (trauma* or injur*)).tw,kw.
Brain contus*.tw,kw.

Concept 2

Exp Family/
Exp Family Functioning/
Exp Caregiver/
Exp Parent/
Family factors.tw,kw.
(family or families).tw,kw.
(parent* or parent-child interact* or dyad).tw,kw.
(mother* or mom or moms or maternal or father* or dad or dads or paternal or brother or sister or sibling*).tw,kw.

Concept 3

Exp Prognosis/
Exp Symptom/
(recover* or prognosis or symptom* or outcome* or postconcussi* or post-concussi*).tw,kw.
((return to or return-to) adj2 (play* or school* or learn*)).tw,kw.

Search = Concept 1 AND Concept 2 AND Concept 3
EMBASE results = 6,355

CINAHL Search Terms

Concept 1

Brain Concussion
Brain Contusions
Brain Injuries
(concussion* or concussed or concussive or subconcuss* or sub-concuss*)
(Mild traumatic brain injur* or mild tbi*)
mtbi*
(Head injur* or head impact* or head trauma*)
(Traumatic brain injur* or tbi*)
(Neurotrauma* or neuro-trauma*)
(Craniocerebral trauma* or Craniocerebral injur*)

Concept 2

Family
Family Relations
Caregivers
Parents
Family factors
(family or families)
(parent* or parent-child interact* or dyad)
(mother* or mom or moms or maternal or father* or dad or dads or paternal or brother or sister or sibling*)

Concept 3

Prognosis
Symptoms
Postconcussion Syndrome
(recover* or prognosis or symptom* or outcome* or postconcussi* or post-concussi*)
((return to play* or return to learn* or return to school*) or (return-to-play* or return-to-learn* or return-to-school*))

Search = Concept 1 AND Concept 2 AND Concept 3
CINAHL results = 3,590

FAD GF Parent Retro

This assessment contains a number of statements about families. Read each statement carefully, and decide how well it describes your own family. You should answer according to how you see your family.

*** Please answer according to how you saw your family before the injury**

For each statement are four (4) possible responses:

Strongly agree (SA)
Check SA if you feel that the statement describes your family very accurately.

Agree (A)
Check A if you feel that the statement describes your family for the most part.

Disagree (D)
Check D if you feel that the statement does not describe your family for the most part.

Strongly disagree (SD)
Check SD if you feel that the statement does not describe your family at all.

Try not to spend too much time thinking about each statement, but respond as quickly and as honestly as you can. If you have difficulty, answer with your first reaction.

1. Planning family activities is difficult because we misunderstand each other.

◯ SA ◯ A ◯ D ◯ SD

2. In times of crisis we can turn to each other for support.

◯ SA ◯ A ◯ D ◯ SD

3. We cannot talk to each other about the sadness we feel.

◯ SA ◯ A ◯ D ◯ SD

4. Individuals are accepted for what they are.

◯ SA ◯ A ◯ D ◯ SD

5. We avoid discussing our fears and concerns.

◯ SA ◯ A ◯ D ◯ SD

6. We can express feelings to each other.

◯ SA ◯ A ◯ D ◯ SD

7. There are lots of bad feelings in the family.

◯ SA ◯ A ◯ D ◯ SD

8. We feel accepted for what we are.

◯ SA ◯ A ◯ D ◯ SD

9. Making decisions is a problem for our family.

◯ SA ◯ A ◯ D ◯ SD

10. We are able to make decisions about how to solve problems.

◯ SA ◯ A ◯ D ◯ SD

11. We don't get along well together.

◯ SA ◯ A ◯ D ◯ SD

12. We confide in each other.

◯ SA ◯ A ◯ D ◯ SD

K6 Parent 3m 6m

The following questions ask about how you have been feeling during the past 30 days. For each question, please circle the number that best describes how often you had this feeling.

	All of the time1	Most of the time2	Some of the time3	A little of the time4	None of the time5
a. ......nervous?	◯	◯	◯	◯	◯
b. ......hopeless?	◯	◯	◯	◯	◯
c. ......restless or fidgety?	◯	◯	◯	◯	◯
d. ......so depressed that nothing could cheer you up?	◯	◯	◯	◯	◯
e. ......that everything was an effort?	◯	◯	◯	◯	◯
f. ......worthless?	◯	◯	◯	◯	◯

ARCS Parent

What happens when your child is injured?

The next questions are about what you do when your child has symptoms related to an injury. For each question, choose one of the answers:

Never
Once in a while
Sometimes
Often
Always

	Never	Once in a while	Sometimes	Often	Always
1. Ask your child what you can do to help?	◯	◯	◯	◯	◯
2. Express irritation or frustration with your child?	◯	◯	◯	◯	◯
3. Do your child chores or pick up your child things instead of making him/her do it?	◯	◯	◯	◯	◯
4. Talk to your child about something else to take off your child's mind of it?	◯	◯	◯	◯	◯
5. Reassure your child that he/she is going to be OK?	◯	◯	◯	◯	◯
6. Get your child something to eat or drink?	◯	◯	◯	◯	◯
7. Bring your child special treats or little gifts?	◯	◯	◯	◯	◯
8. Try not to pay attention to your child?	◯	◯	◯	◯	◯
9. ask your child questions about how he/she feels?	◯	◯	◯	◯	◯

	Never	Once in a while	Sometimes	Often	Always
10. Let your child stay home from school?	◯	◯	◯	◯	◯
11. Encourage your child to do something he or she enjoys (like watch TV or play a game)?	◯	◯	◯	◯	◯

12. Tell your child that he/she doesn't have to finish all of his/her homework?	○	○	○	○	○
13. Tell your child there's nothing you can do about it?	○	○	○	○	○
14. Give your child special privileges?	○	○	○	○	○
15. Stay home from work or come home early (or stay home instead of going out or running errands)?	○	○	○	○	○
16. Tell others in the family not to bother your child or to be especially nice to your child?	○	○	○	○	○
17. Tell your child not to make such a fuss about it?	○	○	○	○	○
18. Pay more attention to your child than usual?	○	○	○	○	○

	Never	Once in a while	Sometimes	Often	Always
19. Let your child sleep in a special place (like in your room or on the couch)?	○	○	○	○	○
20. Tell your child that he/she needs to learn to be stronger?	○	○	○	○	○
21. Let your child sleep later than usual in the morning?	○	○	○	○	○
22. Keep your child inside the house?	○	○	○	○	○
23. Try to involve your child in some activity?	○	○	○	○	○
24. Spend more time than usual with your child?	○	○	○	○	○
25. Try to make your child as comfortable as possible?	○	○	○	○	○
26. Check on your child to see how he/she is doing?	○	○	○	○	○

*CASSS Social Support Scale Child

During this survey, you will be asked to respond to sentences about some form of support or help that you might get from either a parent, a teacher, a classmate, or a close friend. Read each sentence carefully and respond to them honestly. There are no right or wrong answers.

For each sentence you are asked to provide two responses. First, rate how often you receive the support described and then rate how important the support is to you.

My Parents(s)...

1.
...show they are proud of me.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

1b. How important?

◯ Not Important ◯ Important ◯ Very Important

2.
...understand me.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

2b. How important?

◯ Not Important ◯ Important ◯ Very Important

3.
...listen to me when I need to talk.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

3b. How important?

◯ Not Important ◯ Important ◯ Very Important

4.
...make suggestions when I don't know what to do.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

4b. How important?

◯ Not Important ◯ Important ◯ Very Important

5.
...give me good advice.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

5b. How important?

◯ Not Important ◯ Important ◯ Very Important

6.
...help me solve problems by giving me information.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

6b. How important?

◯ Not Important ◯ Important ◯ Very Important

7.
...tell me I did a good job when I do something well.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

7b. How important?

◯ Not Important ◯ Important ◯ Very Important

8.
...nicely tell me when I make mistakes.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

8b. How important?

◯ Not Important ◯ Important ◯ Very Important

9.
...reward me when I've done something well.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

9b. How important?

◯ Not Important ◯ Important ◯ Very Important

10.
...help me practice my activities.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

10b. How important?

◯ Not Important ◯ Important ◯ Very Important

11.
...make time to help me decide things.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

11b. How important?

◯ Not Important ◯ Important ◯ Very Important

12.
...get me many of the things I need.
a. How Often?

◯ Never ◯ Almost Never ◯ Some of the time ◯ Most of the time ◯ Almost Always
◯ Always

12b. How important?

◯ Not Important ◯ Important ◯ Very Important

HBI Parent Pa

Directions: Below is a list of problems that your child may or may not have. For each problem, please rate your child based on since the injury using the scale below.

0=Never, 1=Rarely, 2=Sometimes, 3=Often

	Never 0	Rarely 1	Sometimes 2	Often 3
1. Has trouble sustaining attention	○	○	○	○
2. Is easily distracted	○	○	○	○
3. Has difficulty concentrating	○	○	○	○
4. Has problems remembering what he/she is told	○	○	○	○
5. Has difficulty following directions	○	○	○	○
6. Tends to daydream	○	○	○	○
7. Gets confused	○	○	○	○
8. Is forgetful	○	○	○	○
9. Has difficulty completing tasks	○	○	○	○
10. Has poor problem-solving skills	○	○	○	○
11. Has problems learning	○	○	○	○
12. Has headaches	○	○	○	○
13. Feels dizzy	○	○	○	○
14. Has a feeling that the room is spinning	○	○	○	○
15. Feels faint	○	○	○	○
16. Has blurred vision	○	○	○	○
17. Has double vision	○	○	○	○
18. Experiences nausea	○	○	○	○
19. Gets tired a lot	○	○	○	○
20. Gets tired easily	○	○	○	○

HBI Child Pa

Directions: Below is a list of problems that you may or may not have. For each problem, please rate yourself based on how you have felt since your injury.

0=Never, 1=Rarely, 2=Sometimes, 3=Often

	Never 0	Rarely 1	Sometimes 2	Often 3
1. I have trouble paying attention	○	○	○	○
2. I get easily distracted	○	○	○	○
3. I have a hard time concentrating	○	○	○	○
4. I have problems remembering what people tell me	○	○	○	○
5. I have difficulty following directions	○	○	○	○
6. I daydream too much	○	○	○	○
7. I get confused	○	○	○	○
8. I forget things	○	○	○	○
9. I have problems finishing things	○	○	○	○
10. I have trouble figuring things out	○	○	○	○
11. It's hard for me to learn new things	○	○	○	○
12. I have headaches	○	○	○	○
13. I feel dizzy	○	○	○	○
14. I feel like the room is spinning	○	○	○	○
15. I feel like I'm going to faint	○	○	○	○
16. Things are blurry when I look at them	○	○	○	○
17. I see double	○	○	○	○
18. I feel sick to my stomach	○	○	○	○
19. I get tired a lot	○	○	○	○
20. I get tired easily	○	○	○	○

Appendix G: Model Building and Tests of Model Adequacy

Model 1: Child- and Parent-Reported Cognitive and Somatic PCS after mild TBI and OI

Multi-Trajectory Model

A five-group multi-trajectory model emerged as the preferred model for Model 1 (see Figure 6), in which each trajectory group is defined by a trajectory for four outcomes: child-reported cognitive PCS, parent-reported cognitive PCS, child-reported somatic PCS, and parent-reported somatic PCS, assessed across the first 6-months post-injury.

Model 2: Child- and Parent-Reported Cognitive and Somatic PCS after mild TBI

Child-Reported Cognitive PCS

A six-group trajectory model emerged as the preferred model for child-reported cognitive PCS. Model fit of the six-group model (BIC = -17259.50) significantly improved over a five-group model (BIC = -17344.72) and a one-group model (BIC = -20944.17). The six-group model included additional trajectory groups that were substantively distinct from those captured by the five-group model.

Parent-Reported Cognitive PCS

A six-group trajectory model emerged as the preferred model for parent-reported cognitive PCS. Model fit of the six-group model (BIC = -18729.76) significantly improved over a five-group model (BIC = -18843.15) and a one-group model (BIC = -22876.50). The six-group model included additional trajectory groups that were substantively distinct from those captured by the five-group model.

Child-Reported Somatic PCS

A five-group trajectory model emerged as the preferred model for child-reported somatic PCS. Model fit of the five-group model (BIC = -16083.54) significantly improved over the one-group model (BIC = -18798.67). Although model fit of a six-group model (BIC = -16048.00) improved slightly over the five-group model, the six-group model did not include additional trajectory groups that were substantively distinct from those captured by the five-group model.

Parent-Reported Somatic PCS

A six-group trajectory model emerged as the preferred model for parent-reported cognitive PCS. Model fit of the six-group model (BIC = -15301.44) significantly improved over a five-group model (BIC = -15422.46) and a one-group model (BIC = -17885.03). The six-group model included additional trajectory groups that were substantively distinct from those captured by the five-group model.

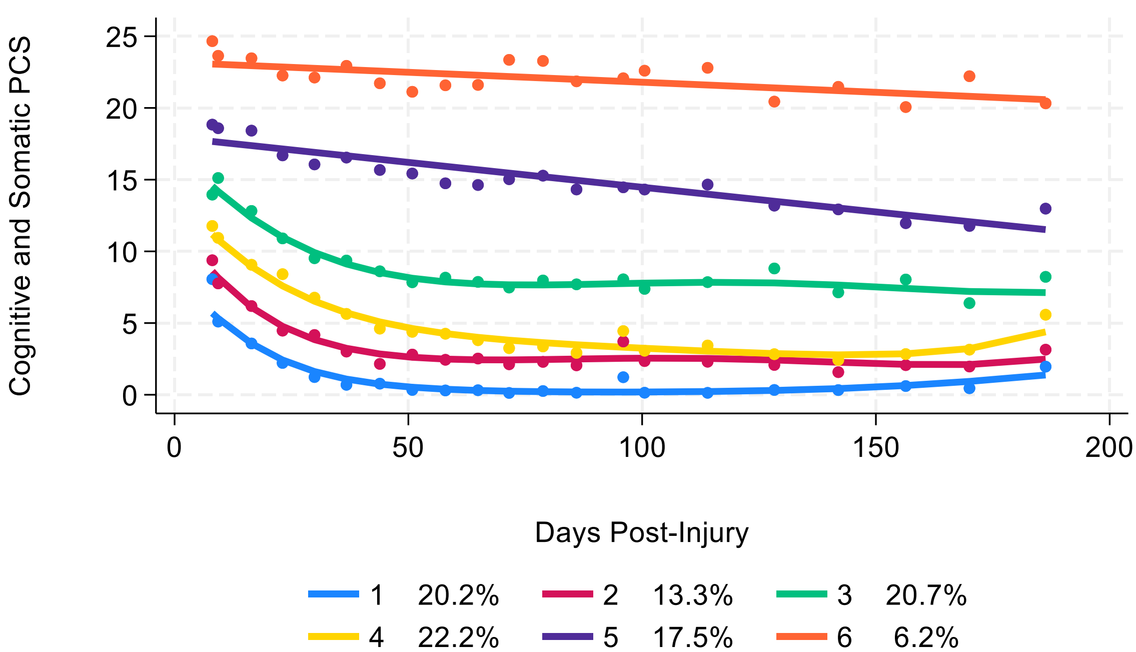
Multi-Trajectory Model

A six-group multi-trajectory model emerged as the preferred model for Model 2 (see Figure 7), in which each trajectory group is defined by a trajectory for four outcomes: child-reported cognitive PCS, parent-reported cognitive PCS, child-reported somatic PCS, and parent-reported somatic PCS, assessed across the first 6-months post-injury, for only the mild TBI sample. Based on the preferred models of the individual outcomes, a five-group model was first estimated. Model fit of the six-group model (BIC = -67977.91) improved over the five-group model (BIC = -68366.42). Although model fit of a seven-group model (BIC = -67757.10) improved slightly over the six-group model, the seven-group model did not include additional trajectory groups that were substantively distinct from those captured by the six-group model. In addition to the BIC comparison, the six-group model performed well on other tests of model adequacy. The proportion of the sample in each trajectory subgroup was greater than the recommended 5%: 20.2% Group 1, 13.3% Group 2, 20.7% Group 3, 22.2% Group 4, 17.5% Group 5, and 6.2% Group 6. The average posterior group probability was greater than the recommended 0.70 for each subgroup: 0.97 Group 1, 0.98 Group 2, 0.95 Group 3, 0.97 Group 4, 0.95 Group 5, and .99 Group 6.

Next, the optimal order and shape of each curve for each trajectory was determined by identifying the highest order statistically significant polynomial term. Polynomials up to quintic terms were estimated for each outcome. Based on the highest order statistically significant polynomial terms, the optimal order and shape of the trajectories for child-reported cognitive PCS was identified as: (3 4 4 4 1 1). The optimal order and shape of the trajectories for parent-reported cognitive PCS was: (3 0 2 3 2 1). The optimal order and shape of the trajectories for child-reported somatic PCS was: (3 4 4 4 4 0). The optimal order and shape of the trajectories for parent-reported somatic PCS was: (3 4 4 4 4 0).

Figure 7

The Final Six-Group Multi-Trajectory Model of Child- and Parent-Reported Cognitive and Somatic PCS after Mild TBI where each Trajectory is Defined by all Four Outcomes



Model 3: Child- and Parent-Reported Cognitive and Somatic PCS after OI

Child-Reported Cognitive PCS

A five-group trajectory model emerged as the preferred model for child-reported cognitive PCS. Model fit of the five-group model (BIC = -8213.21) significantly improved over a four-group model (BIC = -8277.28) and a one-group model (BIC = -10.205.05). Although model fit of a six-group model (BIC = -8212.10) improved slightly over the five-group model, the six-group model did not include additional trajectory groups that were substantively distinct from those captured by the five-group model.

Parent-Reported Cognitive PCS

A six-group trajectory model emerged as the preferred model for parent-reported cognitive PCS. Model fit of the six-group model (BIC = -8580.97) significantly improved over a five-group model (BIC = -8629.43) and a one-group model (BIC = -11151.89). The six-group model included additional trajectory groups that were substantively distinct from those captured by the five-group model.

Child-Reported Somatic PCS

A five-group trajectory model emerged as the preferred model for child-reported somatic PCS. Model fit of the five-group model (BIC = -6959.74) significantly improved over a four-group model (BIC = -8391.69) and a one-group model (BIC = -8391.69). Although model fit of a six-group model (BIC = -6948.30) improved slightly over the five-group model, the six-group model did not include additional trajectory groups that were substantively distinct from those captured by the five-group model.

Parent-Reported Somatic PCS

A four-group trajectory model emerged as the preferred model for parent-reported somatic PCS. Model fit of the four-group model (BIC = -6042.14) significantly improved over a three-group model (BIC = -6151.14) and a one-group model (BIC = -7325.65). Although model fit of a five-group model (BIC = -6019.11) and a six-group model (BIC = -5999.89) improved slightly over the four-group model, the five-group and six-group models did not include additional trajectory groups that were substantively distinct from those captured by the four-group model.

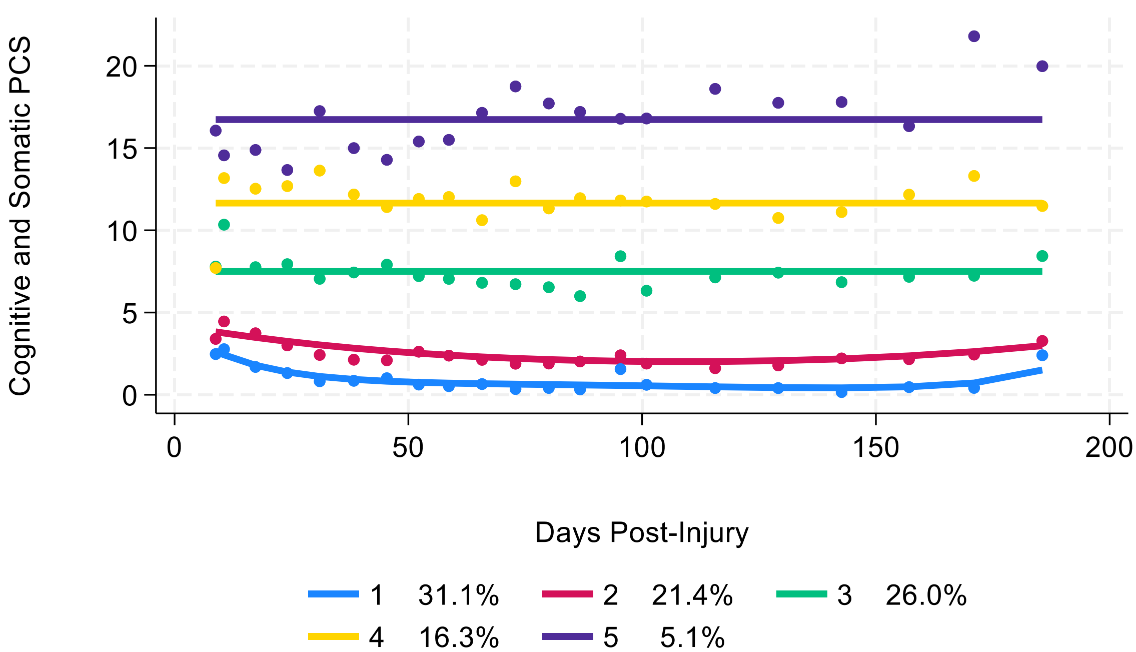
Multi-Trajectory Model

A five-group multi-trajectory model emerged as the preferred model for Model 3 (see Figure 8), in which each trajectory group is defined by a trajectory for four outcomes: child-reported cognitive PCS, parent-reported cognitive PCS, child-reported somatic PCS, and parent-reported somatic PCS, assessed across the first 6-months post-injury. Based on the preferred models of the individual outcomes, a six-group model was first estimated. Model fit of the six-group model (BIC = -32194.97) improved over the five-group model (BIC = -32451.95), however, one of the trajectory subgroups in the six-group model only contained 4.3% of the sample (at least 5% is recommended). Model fit of the five-group model also improved over the four-group model (BIC = -32679.76). In addition to the BIC comparison, the five-group model performed well on other tests of model adequacy. The proportion of the sample in each trajectory subgroup was greater than the recommended 5%: 31.1% Group 1, 21.4% Group 2, 26.0% Group 3, 16.3% Group 4, and 5.1% Group 5. The average posterior group probability was greater than the recommended 0.70 for each subgroup: 0.99 Group 1, 0.98 Group 2, 0.98 Group 3, 0.99 Group 4, and 0.99 Group 5.

Next, the optimal order and shape of each curve for each trajectory group was determined by identifying the highest order statistically significant polynomial term. Polynomials up to quintic terms were estimated for each outcome. Based on the highest order statistically significant polynomial terms, the optimal order and shape of the trajectories for child-reported cognitive PCS was identified as: (4 2 0 0 0). The optimal order and shape of the trajectories for parent-reported cognitive PCS was: (4 0 1 0 1). The optimal order and shape of the trajectories for child-reported somatic PCS was: (4 2 0 0 1). The optimal order and shape of the trajectories for parent-reported somatic PCS was: (4 0 2 0 1).

Figure 8

The Final Five-Group Multi-Trajectory Model of Child- and Parent-Reported Cognitive and Somatic PCS after OI where each Trajectory is Defined by all Four Outcomes



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4) **Representations; Acceptance.** By using the Service, User represents and warrants that User has been duly authorized by the User to accept, and hereby does accept, all Terms.

5) **Scope of License; Limitations and Obligations.** All Works and all rights therein, including copyright rights, remain the sole and exclusive property of the Rightsholder. The License provides only those rights expressly set forth in the terms and conveys no other rights in any Works

6) **General Payment Terms.** User may pay at time of checkout by credit card or choose to be invoiced. If the User chooses to be invoiced, the User shall: (i) remit payments in the manner identified on specific invoices, (ii) unless otherwise specifically stated in an Order Confirmation or separate written agreement, Users shall remit payments upon receipt of the relevant invoice from CCC, either by delivery or notification of availability of the invoice via the Marketplace platform, and (iii) if the User does not pay the invoice within 30 days of receipt, the User may incur a service charge of 1.5% per month or the maximum rate allowed by applicable law, whichever is less. While User may exercise the rights in the License immediately upon receiving the Order Confirmation, the License is automatically revoked and is null and void, as if it had never been issued, if CCC does not receive complete payment on a timely basis.

7) **General Limits on Use.** Unless otherwise provided in the Order Confirmation, any grant of rights to User (i) involves only the rights set forth in the Terms and does not include subsequent or additional uses, (ii) is non-exclusive and non-transferable, and (iii) is subject to any and all limitations and restrictions (such as, but not limited to, limitations on duration of use or circulation) included in the Terms. Upon completion of the licensed use as set forth in the Order Confirmation, User shall either secure a new permission for further use of the Work(s) or immediately cease any new use of the Work(s) and shall render inaccessible (such as by deleting or by removing or severing links or other locators) any further copies of the Work. User may only make alterations to the Work if and as expressly set forth in the Order Confirmation. No Work may be used in any way that is unlawful, including without limitation if such use would violate applicable sanctions laws or regulations, would be defamatory, violate the rights of third parties (including such third parties’ rights of copyright, privacy, publicity, or other tangible or intangible property), or is otherwise illegal, sexually explicit, or obscene. In addition, User may not conjoin a Work with any other material that may result in damage to the reputation of the Rightsholder. Any unlawful use will render any licenses hereunder null and void. User agrees to inform CCC if it becomes aware of any infringement of any rights in a Work and to cooperate with any reasonable request of CCC or the Rightsholder in connection therewith.

8) **Third Party Materials.** In the event that the material for which a License is sought includes third party materials (such as photographs, illustrations, graphs, inserts and similar materials) that are identified in such material as having been used by permission (or a similar indicator), User is responsible for identifying, and seeking separate licenses (under this Service, if available, or otherwise) for any of such third party materials; without a separate license, User may not use such third party materials via the License.

9) **Copyright Notice.** Use of proper copyright notice for a Work is required as a condition of any License granted under the Service. Unless otherwise provided in the Order Confirmation, a proper copyright notice will read substantially as follows: “Used with permission of [Rightsholder’s name], from [Work’s title, author, volume, edition number and year of copyright]; permission conveyed through Copyright Clearance Center, Inc.” Such notice must be provided in a reasonably legible font size and must be placed either on a cover page or in another location that any person, upon gaining access to the material which is the subject of a permission, shall see, or in the case of republication Licenses, immediately adjacent to the Work as used (for example, as part of a by-line or footnote) or in the place where substantially all other credits or notices for the new work containing the republished Work are located. Failure to include the required notice results in loss to the Rightsholder and CCC, and the User shall be liable to pay liquidated damages for each such failure equal to twice the use fee specified in the Order Confirmation, in addition to the use fee itself and any other fees and charges specified.

10) **Indemnity.** User hereby indemnifies and agrees to defend the Rightsholder and CCC, and their respective employees and directors, against all claims, liability, damages, costs, and expenses, including legal fees and expenses, arising out of any use of a Work beyond the scope of the rights granted herein and in the Order Confirmation, or any use of a Work which has been altered in any unauthorized way by User, including claims of defamation or infringement of rights of copyright, publicity, privacy, or other tangible or intangible property.

11) **Limitation of Liability.** UNDER NO CIRCUMSTANCES WILL CCC OR THE RIGHTSHOLDER BE LIABLE FOR ANY DIRECT, INDIRECT, CONSEQUENTIAL, OR INCIDENTAL DAMAGES (INCLUDING WITHOUT LIMITATION DAMAGES FOR LOSS OF BUSINESS PROFITS OR INFORMATION, OR FOR BUSINESS INTERRUPTION) ARISING OUT OF THE USE OR INABILITY TO USE A WORK, EVEN IF ONE OR BOTH OF THEM HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. In any event, the total liability of the Rightsholder and CCC (including their respective employees and directors) shall not exceed the total amount actually paid by User for the relevant License. User assumes full liability for the actions and omissions of its principals, employees, agents, affiliates, successors, and assigns.

12) **Limited Warranties.** THE WORK(S) AND RIGHT(S) ARE PROVIDED "AS IS." CCC HAS THE RIGHT TO GRANT TO USER THE RIGHTS GRANTED IN THE ORDER CONFIRMATION DOCUMENT. CCC AND THE RIGHTSHOLDER DISCLAIM ALL OTHER WARRANTIES RELATING TO THE WORK(S) AND RIGHT(S), EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. ADDITIONAL RIGHTS MAY BE REQUIRED TO USE ILLUSTRATIONS, GRAPHS, PHOTOGRAPHS, ABSTRACTS, INSERTS, OR OTHER PORTIONS OF THE WORK (AS OPPOSED TO THE ENTIRE WORK) IN A MANNER CONTEMPLATED BY USER; USER UNDERSTANDS AND AGREES THAT NEITHER CCC NOR THE RIGHTSHOLDER MAY HAVE SUCH ADDITIONAL RIGHTS TO GRANT.

13) **Effect of Breach.** Any failure by User to pay any amount when due, or any use by User of a Work beyond the scope of the License set forth in the Order Confirmation and/or the Terms, shall be a material breach of such License. Any breach not cured within 10 days of written notice thereof shall result in immediate termination of such License without further notice. Any unauthorized (but licensable) use of a Work that is terminated immediately upon notice thereof may be liquidated by payment of the Rightsholder's ordinary license price therefor; any unauthorized (and unlicensable) use that is not terminated immediately for any reason (including, for example, because materials containing the Work cannot reasonably be recalled) will be subject to all remedies available at law or in equity, but in no event to a payment of less than three times the Rightsholder's ordinary license price for the most closely analogous licensable use plus Rightsholder's and/or CCC's costs and expenses incurred in collecting such payment.

14) **Additional Terms for Specific Products and Services.** If a User is making one of the uses described in this Section 14, the additional terms and conditions apply:

a) ***Print Uses of Academic Course Content and Materials (photocopies for academic coursepacks or classroom handouts).*** For photocopies for academic coursepacks or classroom handouts the following additional terms apply:

i) The copies and anthologies created under this License may be made and assembled by faculty members individually or at their request by on-campus bookstores or copy centers, or by off-campus copy shops and other similar entities.

ii) No License granted shall in any way: (i) include any right by User to create a substantively non-identical copy of the Work or to edit or in any other way modify the Work (except by means of deleting material immediately preceding or following the entire portion of the Work copied) (ii) permit "publishing ventures" where any particular anthology would be systematically marketed at multiple institutions.

iii) Subject to any Publisher Terms (and notwithstanding any apparent contradiction in the Order Confirmation arising from data provided by User), any use authorized under the academic pay-per-use service is limited as follows:

A) any License granted shall apply to only one class (bearing a unique identifier as assigned by the institution, and thereby including all sections or other subparts of the class) at one institution;

B) use is limited to not more than 25% of the text of a book or of the items in a published collection of essays, poems or articles;

C) use is limited to no more than the greater of (a) 25% of the text of an issue of a journal or other periodical or (b) two articles from such an issue;

D) no User may sell or distribute any particular anthology, whether photocopied or electronic, at more than one institution of learning;

E) in the case of a photocopy permission, no materials may be entered into electronic memory by User except in order to produce an identical copy of a Work before or during the academic term (or analogous period) as to which any particular permission is granted. In the event that User shall choose to retain materials that are the subject of a photocopy permission in electronic memory for purposes of producing identical copies more than one day after such retention (but still within the scope of any permission granted), User must notify CCC of such fact in the applicable permission request and such retention shall constitute one copy actually sold for purposes of calculating permission fees due; and

F) any permission granted shall expire at the end of the class. No permission granted shall in any way include any right by User to create a substantively non-identical copy of the Work or to edit or in any other way modify the Work (except by means of deleting material immediately preceding or following the entire portion of the Work copied).

iv) Books and Records; Right to Audit. As to each permission granted under the academic pay-per-use Service, User shall maintain for at least four full calendar years books and records sufficient for CCC to determine the numbers of copies made by User under such permission. CCC and any representatives it may designate shall have the right to audit such books and records at any time during User's ordinary business hours, upon two days' prior notice. If any such audit shall determine that User shall have underpaid for, or underreported, any photocopies sold or by three percent (3%) or more, then User shall bear all the costs of any such audit; otherwise, CCC shall bear the costs of any such audit. Any amount determined by such audit to have been underpaid by User shall immediately be paid to CCC by User, together with interest thereon at the rate of 10% per annum from the date such amount was originally due. The provisions of this paragraph shall survive the termination of this License for any reason.

b) ***Digital Pay-Per-Uses of Academic Course Content and Materials (e-coursepacks, electronic reserves, learning management systems, academic institution intranets).*** For uses in e-coursepacks, posts in electronic reserves, posts in learning management systems, or posts on academic institution intranets, the following additional terms apply:

i) The pay-per-uses subject to this Section 14(b) include:

A) **Posting e-reserves, course management systems, e-coursepacks for text-based content,** which grants authorizations to import requested material in electronic format, and allows electronic access to this material to members of a designated college or university class, under the direction of an instructor designated by the college or university, accessible only under appropriate electronic controls (e.g., password);

B) **Posting e-reserves, course management systems, e-coursepacks for material consisting of photographs or other still images not embedded in text,** which grants not only the authorizations described in Section 14(b)(i)(A) above, but also the following authorization: to include the requested material in course materials for use consistent with Section 14(b)(i)(A) above, including any necessary resizing, reformatting or modification of the resolution of such requested material (provided that such modification does not alter the underlying editorial content or meaning of the requested material, and provided that the resulting modified content is used solely within the scope of, and in a manner consistent with, the particular authorization described in the Order Confirmation and the Terms), but not including any other form of manipulation, alteration or editing of the requested material;

C) **Posting e-reserves, course management systems, e-coursepacks or other academic distribution for audiovisual content,** which grants not only the authorizations described in Section 14(b)(i)(A) above, but also the following authorizations: (i) to include the requested material in course materials for use consistent with Section 14(b)(i)(A) above; (ii) to display and perform the requested material to such members of such class in the physical classroom or remotely by means of streaming media or other video formats; and (iii) to "clip" or reformat the requested material for purposes of time or content management or ease of delivery, provided that such "clipping" or reformatting does not alter the underlying editorial content or meaning of the requested material and that the resulting material is used solely within the scope of, and in a manner consistent with, the particular authorization described in the Order Confirmation and the Terms. Unless expressly set forth in the relevant Order Conformation, the License does not authorize any other form of manipulation, alteration or editing of the requested material.

ii) Unless expressly set forth in the relevant Order Confirmation, no License granted shall in any way: (i) include any right by User to create a substantively non-identical copy of the Work or to edit or in any other way modify the Work (except by means of deleting material immediately preceding or following the entire portion of the Work copied or, in the case of Works subject to Sections 14(b)(1)(B) or (C) above, as described in such Sections) (ii) permit "publishing ventures" where any particular course materials would be systematically marketed at multiple institutions.

iii) Subject to any further limitations determined in the Rightsholder Terms (and notwithstanding any apparent contradiction in the Order Confirmation arising from data provided by User), any use authorized under the electronic course content pay-per-use service is limited as follows:

A) any License granted shall apply to only one class (bearing a unique identifier as assigned by the institution, and thereby including all sections or other subparts of the class) at one institution;

B) use is limited to not more than 25% of the text of a book or of the items in a published collection of essays, poems or articles;

C) use is limited to not more than the greater of (a) 25% of the text of an issue of a journal or other periodical or (b) two articles from such an issue;

D) no User may sell or distribute any particular materials, whether photocopied or electronic, at more than one institution of learning;

E) electronic access to material which is the subject of an electronic-use permission must be limited by means of electronic password, student identification or other control permitting access solely to students and instructors in the class;

F) User must ensure (through use of an electronic cover page or other appropriate means) that any person, upon gaining electronic access to the material, which is the subject of a permission, shall see:

- a proper copyright notice, identifying the Rightsholder in whose name CCC has granted permission,

- a statement to the effect that such copy was made pursuant to permission,
- a statement identifying the class to which the material applies and notifying the reader that the material has been made available electronically solely for use in the class, and
- a statement to the effect that the material may not be further distributed to any person outside the class, whether by copying or by transmission and whether electronically or in paper form, and User must also ensure that such cover page or other means will print out in the event that the person accessing the material chooses to print out the material or any part thereof.

G) any permission granted shall expire at the end of the class and, absent some other form of authorization, User is thereupon required to delete the applicable material from any electronic storage or to block electronic access to the applicable material.

iv) Uses of separate portions of a Work, even if they are to be included in the same course material or the same university or college class, require separate permissions under the electronic course content pay-per-use Service. Unless otherwise provided in the Order Confirmation, any grant of rights to User is limited to use completed no later than the end of the academic term (or analogous period) as to which any particular permission is granted.

v) Books and Records; Right to Audit. As to each permission granted under the electronic course content Service, User shall maintain for at least four full calendar years books and records sufficient for CCC to determine the numbers of copies made by User under such permission. CCC and any representatives it may designate shall have the right to audit such books and records at any time during User's ordinary business hours, upon two days' prior notice. If any such audit shall determine that User shall have underpaid for, or underreported, any electronic copies used by three percent (3%) or more, then User shall bear all the costs of any such audit; otherwise, CCC shall bear the costs of any such audit. Any amount determined by such audit to have been underpaid by User shall immediately be paid to CCC by User, together with interest thereon at the rate of 10% per annum from the date such amount was originally due. The provisions of this paragraph shall survive the termination of this license for any reason.

c) ***Pay-Per-Use Permissions for Certain Reproductions (Academic photocopies for library reserves and interlibrary loan reporting) (Non-academic internal/external business uses and commercial document delivery).*** The License expressly excludes the uses listed in Section (c)(i)-(v) below (which must be subject to separate license from the applicable Rightsholder) for: academic photocopies for library reserves and interlibrary loan reporting; and non-academic internal/external business uses and commercial document delivery.

i) electronic storage of any reproduction (whether in plain-text, PDF, or any other format) other than on a transitory basis;

ii) the input of Works or reproductions thereof into any computerized database;

iii) reproduction of an entire Work (cover-to-cover copying) except where the Work is a single article;

iv) reproduction for resale to anyone other than a specific customer of User;

v) republication in any different form. Please obtain authorizations for these uses through other CCC services or directly from the rightsholder.

Any license granted is further limited as set forth in any restrictions included in the Order Confirmation and/or in these Terms.

d) ***Electronic Reproductions in Online Environments (Non-Academic-email, intranet, internet and extranet).*** For "electronic reproductions", which generally includes e-mail use (including instant messaging or other electronic transmission to a defined group of recipients) or posting on an intranet, extranet or Intranet site (including any display or performance incidental thereto), the following additional terms apply:

i) Unless otherwise set forth in the Order Confirmation, the License is limited to use completed within 30 days for any use on the Internet, 60 days for any use on an intranet or extranet and one year for any other use, all as measured from the "republication date" as identified in the Order Confirmation, if any, and otherwise from the date of the Order Confirmation.

ii) User may not make or permit any alterations to the Work, unless expressly set forth in the Order Confirmation (after request by User and approval by Rightsholder); provided, however, that a Work consisting of photographs or other still images not embedded in text may, if necessary, be resized, reformatted or have its resolution modified without additional express permission, and a Work consisting of audiovisual content may, if necessary, be "clipped" or reformatted for purposes of time or content management or ease of delivery (provided that any such resizing, reformatting, resolution modification or "clipping" does not alter the underlying editorial content or meaning of the Work used, and that the resulting material is used solely within the scope of, and in a manner consistent with, the particular License described in the Order Confirmation and the Terms.

15) **Miscellaneous.**

a) User acknowledges that CCC may, from time to time, make changes or additions to the Service or to the Terms, and that Rightsholder may make changes or additions to the Rightsholder Terms. Such updated Terms will replace the prior terms and conditions in the order workflow and shall be effective as to any subsequent Licenses but shall not apply to Licenses already granted and paid for under a prior set of terms.

b) Use of User-related information collected through the Service is governed by CCC's privacy policy, available online at www.copyright.com/about/privacy-policy/.

c) The License is personal to User. Therefore, User may not assign or transfer to any other person (whether a natural person or an organization of any kind) the License or any rights granted thereunder; provided, however, that, where applicable, User may assign such License in its entirety on written notice to CCC in the event of a transfer of all or substantially all of User's rights in any new material which includes the Work(s) licensed under this Service.

d) No amendment or waiver of any Terms is binding unless set forth in writing and signed by the appropriate parties, including, where applicable, the Rightsholder. The Rightsholder and CCC hereby object to any terms contained in any writing prepared by or on behalf of the User or its principals, employees, agents or affiliates and purporting to govern or otherwise relate to the License described in the Order Confirmation, which terms are in any way inconsistent with any Terms set forth in the Order Confirmation, and/or in CCC's standard operating procedures, whether such writing is prepared prior to, simultaneously with or subsequent to the Order Confirmation, and whether such writing appears on a copy of the Order Confirmation or in a separate instrument.

e) The License described in the Order Confirmation shall be governed by and construed under the law of the State of New York, USA, without regard to the principles thereof of conflicts of law. Any case, controversy, suit, action, or proceeding arising out of, in connection with, or related to such License shall be brought, at CCC's sole discretion, in any federal or state court located in the County of New York, State of New York, USA, or in any federal or state court whose geographical jurisdiction covers the location of the Rightsholder set forth in the Order Confirmation. The parties expressly submit to the personal jurisdiction and venue of each such federal or state court.

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