# From Concussion to Classroom: Predicting Post-Concussion Pediatric School Functioning

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## Abstract

Pediatric concussion is a common injury that can impact many children annually, and while most children return to school within 2 weeks post-concussion, many experience ongoing symptoms that can significantly impair school functioning. Moreover, children with pre-existing learning conditions may be at even greater risk for delayed return-to-learn. However, there is limited research examining what factors predict school functioning 1 month post-concussion. Therefore, this study aimed to investigate whether initial post-concussion symptom severity predicted school functioning outcomes at 1 month post-concussion, while accounting for pre-existing learning conditions and demographics.

This research involved 275 children and adolescents aged 5-17 years old who had sustained a concussion. Parent reports were analysed which included the Post-Concussion Symptom Inventory and Pediatric Quality of Life Inventory, as well as study specific demographic questions. We used a hierarchical multiple linear regression to examine whether initial PCSI symptom severity predicted PedsQL school functioning outcomes at 1 month post-concussion, while accounting for pre-existing learning conditions and demographics.

The results showed that more severe initial PCSI symptoms significantly predicted worse school functioning outcomes at 1 month post-concussion ($R^2$ = .12, F(6, 158) = 3.53, $p$ = .003), supporting our main hypothesis. However, pre-existing learning conditions did not significantly predict school functioning outcomes, which failed to support our second hypothesis. The final model accounted for 11.8 percent of the variance in school functioning outcomes.

In conclusion, this research demonstrates that initial post-concussion symptom severity predicts school functioning outcomes at 1 month post-concussion, while pre-existing learning conditions did not. These findings highlight the importance of comprehensive symptom assessment and individualised support plans for children returning to school.

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# Introduction

This introduction examines the literature concerning concussion and the impact it has on children and adolescents school functioning. To start, information regarding the definition of concussion and the common causes of concussion in children is provided. This is followed by the prevalence and incidence rates of concussion in children to establish the public health significance of this form of Traumatic Brain Injury. The introduction then details common symptoms of concussion and persistent symptoms of concussion, alongside symptom assessment methods and current approaches to recovery and treatment. Finally, research into the relationship between concussion and students returning to school is explored, highlighting the challenges students may face cognitively and socially. The impact pre-existing learning conditions may have on a student has also been highlighted.

## Definition of Concussion

Traumatic Brain Injury (TBI) occurs when a sudden external force disrupts the structure of the brain (Pervez et al., 2018; Sussman et al., 2018). Concussion is a common condition that is recognised as a mild form of TBI among adult and pediatric populations (Hon et al., 2019; Kazl & Torres, 2019). Within the clinical literature, there are an array of definitions for concussion and mild traumatic brain injury (mTBI), which has caused confusion among research findings (Sussman et al., 2018). Some practitioners believe the term concussion defines the neurological impairments that occur in response to a head knock (McKinlay et al., 2011), yet others believe the terms concussion and mTBI can be used interchangeably (McKinlay et al., 2011; Sussman et al., 2018). The term concussion appears to be more commonly used within sports medicine literature (McNamee et al., 2016; Musumeci et al., 2019), whereas mTBI appears most among the general medical literature (Lefevre-Dognin et al., 2021; McInnes et al., 2017).

The World Health Organisation (WHO) offers a criteria to define a concussion. The patient must have at least one or more of the following: confusion or disorientation, loss of consciousness for 30 minutes or less, post-traumatic amnesia for less than 24 hours, or other abnormalities such as a seizure, intracranial lesions that don't require surgery and focal signs (Carroll, 2004). Alongside this, practitioners should also use the Glasgow Coma Scale (GCS) developed by Teasdale & Jennett (1974) to assess level of consciousness. The scale consists of three components, with a total score of 15 points: motor response (6 points), verbal response (5 points), and eye-opening (4 points). The GCS categorises the severity of TBI as mild, moderate or severe. TBI is diagnosed as mild with a score between 13 and 15 points, moderate with a score between 9 and 12 points and severe with a score of 8 points or less (Teasdale & Jennett, 1974). Therefore, the WHO suggests the patient must also receive a GCS score of 13 to 15 points after 30 minutes post-concussion or later upon assessment from a medical professional to inform the diagnosis of concussion (Caroll et al., 2004). For the purpose of this research, the term concussion will be used throughout. It is important to note that concussion is a clinical diagnosis, one of which there is currently no accurate lab testing or neuroimaging involved (McVige et al., 2018). Mcvige and colleagues (2018) study found abnormalities in only 8 percent of Computed Tomography (CT) scans and 24 percent of MRI scans.

Common causes of concussion among pediatric populations include sports-related injuries, falling off a non-motor vehicle, such as a bike, scooter, or skateboard and vehicle accidents (Yengo-Kahn et al., 2021). Sports-related concussions account for an estimated 30 percent of incidents globally (Breck et al., 2019). Yengo-Kahn (2021) found falls and being struck by an object were the most common causes of concussion in children aged 5 to 14 years old (35%), and falls being the most common cause in children under 4 years old (70%).

In New Zealand, a study reported commons causes of TBI to be falls (38%), mechanical force (21%), motor vehicle accident (20%) and assault (17%) (Feigin et al., 2013).

**Prevalence and Incidence of Concussion**

Concussion has a significant impact on children and adolescents globally, with reports of concussion increasing (Langer et al., 2020). Veliz and colleagues (2021) found that the prevalence of self-reported concussions in the United States of America (US) increased from 19.5 percent in 2016, to 24.6 percent in 2020. Various studies that examined the prevalence of concussion among both youth and adult populations, estimated a wide range of 2.5 and 25 percent (Dufour et al., 2020; Haarbauer-Krupa et al., 2021; Veliz et al., 2021; Waltzman & Daugherty, 2018). Limitations of self-report measures and under-reporting may account for the lack of a consistent prevalence (Giromini et al., 2022).

It is widely acknowledged that the true incidence of concussion is underestimated (Lefevre-Dognin et al., 2021). A study in the US reported to have 1.7 million to 3.8 million people both diagnosed and undiagnosed with a concussion annually (Cheng et al., 2019). Whereas, there are an estimated 749 per 100,000 people diagnosed with concussion across all ages annually in New Zealand (Feigin et al., 2013). Feigin and colleagues (2013) found individuals aged 0 to 34 made up almost 70 percent of the incidence of TBI in New Zealand. The estimated incidence of sports-related concussions from hospital based studies in New Zealand is between 3.5 and 31.5 per 100,000 (Theadom et al., 2020) Cancelliere and colleagues (2017) examined data from emergency departments (ED) in the US between 2006 and 2012 to analyse the rates of concussion. They found the highest rates of concussion were children aged 0 to 4 (1417/100,000) and males aged 15 to 24 (966/100,000) (Cancelliere et al., 2017). Furthermore, Langer and colleagues (2020) found children younger than 5 years old had the highest estimated incidence of non-sports-related concussions as 5400 per 100,000 children in Ontario, Canada between 2008 and 2016. The discrepancy between recorded cases of concussion and true cases of concussion may be due to the small proportion of patients that actually visit a hospital or clinic for diagnosis (Lefevre-Dognin et al., 2021). Furthermore, most of the current literature focuses on participants recruited through hospitals, which may lead to systematic biases by over or underestimating the true population of concussion cases (Starkey et al., 2018). It is important to acknowledge the incidence and prevalence of concussion among youth to further understand the significance the injury has on the public health system. This information provides insight to help the development of adequate care and concussion management strategies, aiming to reduce concussion burden on children and adolescents.

**Symptoms of Concussion**

Post-concussive symptoms can be categorised as cognitive, physical and emotional (Sady et al., 2014). To explain how concussive symptoms occur, it is important to understand the pathophysiological response to a sudden blow to the head. The pathophysiological response to a concussion includes a neurometabolic cascade of events (Wells et al., 2016). An abrupt force to the head injures the central nervous system (CNS) which leads to cerebral dysfunction in the brain, without significant cell death (MacFarlane & Glenn, 2015). Essentially, the brain cells react by being flooded with ions and burning through energy reserves, trying to return to homeostasis (MacFarlane & Glenn, 2015). This leads to a temporary disruption in the brains typical communication and metabolic processes, resulting in the cognitive, emotional and physical symptoms that commonly present themselves (MacFarlane & Glenn, 2015).

Common acute symptoms post injury may include headaches, nausea, dizziness, fatigue, sensitivity to light or noise, sleep disturbances, visual problems and balance issues (Junn et al., 2015). Eisenberg and colleagues (2014) examined the acute symptoms of concussion through a prospective study with patients aged 11 to 22 years. They found headaches (85.1%), fatigue (64.2%) and dizziness (61.3%) were the most acute symptoms presented within 72 hours of obtaining the head injury (Eisenberg et al., 2014). Likewise, Starkey and colleagues (2018) found headaches, fatigue, dizziness and irritability to be the most common acute symptoms of concussion in New Zealand children and adolescents aged 8 to 15 years. Moreover, Blume (2015) found headaches to be the most common acute symptom of concussion. Most people will typically recover within 1 to 2 weeks, but a minority suffering from persistent headaches for up to 12 months (Blume, 2015).

Cognitive symptoms among children may include attention deficits, memory issues, trouble thinking clearly, feeling slowed down and feeling mentally foggy (Junn et al., 2015). Common attention deficits after a concussion include reduced organisation, difficulty maintaining focus and slower processing speed. Memory challenges can be exhibited through difficulty learning new information, short-term memory impairment and reduced working memory capacity (Junn et al., 2015). A child or adolescent experiencing executive functioning issues after a concussion may experience problem-solving problems, challenges in planning and reduced cognitive flexibility (Junn et al., 2015). Typically, a concussion does not result in severe cognitive symptoms post-concussion compared to more severe TBI's, although research suggests specific neurocognitive symptoms may occur (Babikian et al., 2011). Catale and colleagues (2009) reported deficits in memory and attention in children with mTBI one-year post-concussion. Children with mTBI were compared with a control group and were assessed using the Connors Parents Rating Scale (CPRS-R), the Wechsler Intelligence Scale third edition (WISC-III) and computerized tasks from the Test of Attentional Performance (TAP) battery that measured attention and working memory (Catale et al., 2009). Their research suggested children with mTBI may be more vulnerable to attention and executive functioning difficulties one-year post-concussion (Catale et a., 2009).

Furthermore, emotional and social symptoms are important for understanding concussion management. These symptoms may include irritability, sadness, nervousness, emotional dysregulation and social isolation (Wilmoth et al., 2019). Mood changes, such as feeling sad or irritable, have been directly associated with concussion among children and adolescents (Wilmoth et al., 2019). Luis and Mittenberg (2002) examined mood disruptions in children 6-15 years post-concussion. They discovered children were nine times more likely to experience mood disruptions 6 months post-concussion, compared to a population with a skeletal injury (Luis & Mittenberg, 2002). Starkey and colleagues (2018) found emotional symptoms to be more prominent in children and adolescents in the post-acute phase (90 days post-concussion), which included frustration and irritability.

**Persistent Post-Concussive Symptoms**

Although symptoms typically resolve within 1 week to 3 months, persistent post-concussive symptoms (PPCS) may occur up to a year or more post-concussion (Cnossen et al., 2018; Ponsford et al., 2019). PPCS is diagnosed when concussive symptoms persist for longer than 4 weeks post injury (Chadwick et al., 2022). Starkey and colleagues (2018) found the most persistent-concussive symptoms in children and adolescents aged 8 to 15 years to be irritability, frustration, forgetfulness and fatigue. Blume and colleagues (2015) examined symptoms of concussion 3 months after injury. Their study found 43 percent of children reported to have ongoing headaches at 3 months post-concussion (Blume, 2015). The prevalence for children with PPCS is estimated to be between 10 and 35 percent (Chadwick et al., 2022; Cnossen et al., 2018; Zemek et al., 2013). Although, estimates may vary due to factors such as sex and age (Chadwick et al., 2022). Chadwick and colleagues (2022) conducted a meta-analysis of 13 studies to estimate the true proportion of children and adolescents with PPCS. Their research suggests the estimated proportion to be 35.1 percent who experienced symptoms for longer than 4 weeks post-concussion (Chadwick et al., 2022).

Currently, there are no successful models that predict PPCS in a clinical setting (Cnossen et al., 2018). Although, many studies aim to identify risk factors that could be associated with PPCS (Blume et al., 2015; Cnossen et al., 2018; Zemek et al., 2013). These factors may include genetics, having a history of concussions and other clinical factors (Dharsee et al., 2024). Dharsee and colleagues (2024) identified potential predictors of PPCS to include being female, having psychiatric and learning problems pre-injury, being older and having ineffective coping strategies. Zemek and colleagues (2013) found adolescents were at higher risk of developing PPCS than children. Their research suggests this may be associated with adolescents having more severe accidents, such as motor vehicle accidents, sports collisions and assaults, resulting in a higher level of damage at the cellular level (Zemek et al., 2013). Zemek and colleagues (2013) also found adolescents may be better at communicating their symptoms than children, and therefore understanding the severity of their symptoms more accurately. Furthermore, Chadwick and colleagues' (2022) meta-analysis demonstrated adolescents may be more vulnerable to PPCS as their brain is undergoing rapid development in regions such as the anterior, where the frontal lobes of the brain are located, which play a crucial role in cognitive and executive functioning, and is known to be particularly vulnerable to TBI. As the rates of PPCS in children and adolescents are relatively high, it is crucial to identify appropriate assessment tools for early intervention and symptom management.

**Assessment of Symptoms**

There have been various psychometric tools developed to assess symptoms of concussion in both adult and pediatric populations. The most commonly known scales to assess concussion symptoms are the Rivermead Post-Concussion Symptoms Questionnaire (RPQ), the Health and Behaviour Inventory (HBI), the Neurobehavioral Symptom Inventory (NSI), the Post-Concussion Symptom Scale (PCSS) and more recently the Post-Concussion Symptom

Inventory (PCSI) (Balalla et al., 2020; Langevin et al., 2022; Sady et al., 2014; Vos et al., 2019; Zhang et al., 2023). The PCSI scale is derived from Lovell and Collins (1998) Post Concussion Scale (PCS), which was originally developed for sports-related concussions in adults (Lovell & Collins, 1998; Sady et al., 2014). As the PCSI is relatively new in comparison to the previously mentioned scales, it is important to acknowledge some of the key differences. The PCSI was modified to suit the needs and capabilities of children and adolescents. The modified version uses self-report measures and categorises the forms per age group; 5-7 years old (5 items), 8-12 years old (17 items), 13-17 years old (21 items) and a parent-reported form for children aged 5-17 years old (20 items) (Sady et al., 2014). The different forms were created to meet the developmental needs of the child and adolescent, for example, the wording was simplified for children 5-7 years old, using words such as 'tired' rather than 'fatigued.'

Although the HBI also assesses concussion symptoms in children and adolescents, the scale focuses on symptom frequency rather than symptom severity (Ayr et al., 2009). Furthermore, whilst the HBI and PCSI assess similar domains (cognitive, physical and emotional), the PCSI also assesses children's sleep symptoms (Gioia et al., 2019). The published version of the PCSI-2 uses Retrospective Adjusted Post-concussion Difference (RAPID) scores from pre-injury baseline symptom severity to their current symptom severity, to assess symptom changes at each timepoint. As the PCSI is a self-report questionnaire, the integrity of the results relies on the participants being honest and accurate with their answers. Although, it is common for participants to report concussion symptoms inaccurately, such as over or under-exaggerating symptoms (Araujo et al., 2014). Araujo and colleagues (2014) research suggests children and adolescents diagnosed with concussion who also fail effort testing, may be more likely to exaggerate concussive symptoms. Despite the formally mentioned psychometrics are deemed appropriate for assessing symptoms of concussion, there are other methods to collect this information. Clinical examinations including ocular examination, assessing balance, and mental status have been identified to be useful when evaluating a concussion. Although, these methods appear to lack robust validity (Matuszak et al., 2016).

Sady and colleagues (2014) examined the psychometric characteristics of the PCSI, finding strong internal consistency for the total scales, and test-retest reliability was moderate to strong for the self-report forms. Sady and colleagues (2014) also identified parent and child concordance as moderate. Gioia (2016) further examined the psychometric properties of the PCSI. They found each of the versions of the PCSI demonstrated good convergent validity, discriminant validity, concurrent validity and criterion validity, as well as good internal consistency, test-retest reliability and inter-rater reliability (Gioia, 2016). Gioia and colleagues (2019) further provided reliability and validity measures for the parent, child and adolescent versions of the PCSI-2. For reliability, internal consistency for the total and subscale RAPID scores was strong and test-retest reliability for the RAPID scores and retrospective baseline ratings (RBL) were moderate to strong (Gioia et al., 2019). Convergent validity, which is the ability to show a measure is correlated with other similar measures, was reported to be good from the significantly strong correlation between the PCSI-2 and the Acute Concussion Evaluation (ACE) battery (Gioia et al., 2019). Moreover, correlations between the PCSI-2 and the School Problems scale of the Concussion Learning Assessment and School Survey version 3 (CLASS-3) demonstrated a significant medium to strong association, providing validity that the scale relates to a child's functioning in a school setting (Gioia et al., 2019). Overall, as the PSCI has been deemed an appropriate measure to assess concussive symptoms in children and adolescents, it is important to acknowledge how the information gathered from these assessments aid in establishing appropriate recovery protocols and treatment.

**Recovery and Treatment of Concussion**

Cognitive rest during the first 2-4 days post-concussion is a typical recommendation from professionals for recovery (Brown et al., 2014). However, some medical professionals advise their patients to rest until asymptomatic (McCrory et al., 2013). Brown and colleagues (2014) discovered that cognitive rest during the initial recovery period reduced the longevity of post-concussive symptoms in athletes. However, they used only athletes in their sample, which limits the generalisability of their findings to the wider population. Schneider and colleagues (2017) conducted a systematic review to determine the impact cognitive rest until asymptomatic has on recovery. In their review, other studies suggested that athletes would benefit from longer periods of rest due to the physical nature and energy demands sport places on the brain and body (Schneider et al., 2017). Schneider and colleagues (2017) demonstrated initial cognitive and physical rest may promote quicker neurometabolic restoration by minimising energy exertion. However, the results from their study suggests complete rest until asymptomatic does not facilitate concussion recovery. Adolescents who were prescribed 5 days of rest reported to have more symptoms 10 days post-concussion, compared to those who received advice to rest for 1-2 days (Schneider et al., 2017).

Additionally, research suggests too much cognitive rest can be equally as detrimental to recovery as no cognitive rest (Silverberg et al., 2016). Silverberg and Otamendi (2016) identified the potential harm of resting until asymptomatic and the impact it may have on return-to-learn (RTL) and activities. Vaughan and colleagues (2023) examined whether an earlier RTL exacerbated post-concussive symptoms in children and adolescents aged 5 to 18 years. They examined 1630 female and male children and adolescents with 875 returning to learn earlier than 2 weeks. Their research suggests an earlier RTL is associated with lower symptom burden, compared to RTL 2 weeks post-concussion (Vaughan et al., 2023). Both studies support growing evidence of the potential negative impact prolonged rest has on the brain after concussion (Silverberg et al., 2016; Vaughan et al., 2023). Furthermore, longitudinal observation of symptom recovery over 12 months would allow for crucial insight into the trajectory of concussion symptoms in pediatric populations.

Alongside cognitive rest, there is a developing body of research around the benefits of physical rest (Lal et al., 2018). Patients diagnosed with a concussion are typically advised to abstain from physical activity for at least 2 weeks, or until symptom resolution (Lempke et al., 2019). Lal and Colleague's (2018) conducted a systematic review to evaluate the role of physical activity post-concussion. They determined low impact physical exercise, such as walking, improves cognitive scores on the Post-Concussive Symptom Scale (PCSS) (Lal et al., 2018). Although, they were unable to identify why patients had a decrease in symptoms after exercising. It is thought that due to the pathophysiological cascade that occurs after a concussion, there is a decrease in cerebral blood flow (Lal et al., 2018). Exercise improves cerebral blood flow, among other neurovascular functions (Rooks et al., 2010), which could be a potential factor in the decrease of PCSS scores and improvement in concussion recovery (Lal et al., 2018).

**School Functioning After Concussion**

Concussive symptoms can be a significant issue for children and adolescents when returning to school. Currently, there is an inconsistency in guidelines globally for academic, emotional and social support when returning to school post-concussion (Wan & Nasr, 2021). The current literature suggests a 2-4 day rest period before returning to school (Kemp & O'Brien, 2022). As per the return-to-school guidelines from Accident Compensation Corporation (ACC) Zealand, children and adolescents are advised to have 1-2 days off school following the initial injury (Accident Compensation Corporation, 2011). The Ministry of Education (MoE) New Zealand advises a gradual return-to-school, that follows guidance from health professionals. The guidance is typically individualised and based on the needs of the child or adolescent (Ministry of Education, 2025). Common guidelines in the literature include limiting school work, writing, reading and other activities that may be too visually stimulating (Romm et al., 2018). Additionally, symptoms of concussion when returning to school may worsen and commonly include headaches, dizziness, light sensitivity, noise sensitivity, and difficulty concentrating and remembering things (Halstead et al., 2013). It is critical to understand the implications when returning to school after a concussion to ensure proper support protocols are put in place.

### *Cognitive Implications*

The primary concern of return-to-learn after a concussion is the cognitive impact it has on the child or adolescent (Schneider et al., 2016). A concussion diagnosis can disrupt multiple cognitive domains that are essential for academic success. An important domain is attention and concentration. Initial concussion symptoms often reduce the ability to process information effectively, increase distractibility and reduce working-memory capabilities (Brown et al., 2014). Executive functioning as a cognitive domain represents planning and organisational skills. Disruptions in this domain can impact the preparation and completion of academic tasks, time management of academic activities and problem-solving abilities (Schneider et al., 2016). Lastly, the ability to process information as a cognitive domain is important for academic success. Children and adolescents with a concussion may struggle to process information quickly, have increased cognitive fatigue and reduced comprehension rates (Schneider et al., 2016). Current research suggests that returning to learn within 48 hours post-concussion can predict positive academic outcomes (Peng & Kievit, 2020).

### *Emotional and Social Implications*

Students returning to school post-concussion may also experience challenges with social re-integration. While most students return to school and activities relatively quickly after a concussion, some may find the transition rather demanding. The likelihood of social isolation is somewhat low, although for those who have more persistent post-concussive symptoms and need more time off school, they may experience difficulties reintegrating back into their regular social groups and activities (Davies et al., 2020). Emotional dysregulation can also impact a student's school functioning and overall well-being (Davies et al., 2020). This may be observed through increased irritability, reduced stress tolerance and heightened anxiety around academic performance (Davies et al., 2020).

To better understand the impact concussion has on students returning to school, Davies and colleagues (2019) conducted a qualitative study where they interviewed eight adolescents and young adults who were diagnosed with serious emotional and social symptoms from a concussion in their youth. Researchers used Grounded Theory to create a theoretical model to categorise and explain the participants emotional and social issues (Davies et al., 2020). Categories that emerged from the analysis included anxiety, depression, social isolation and irritability, all of which are considered potential symptoms of post-concussion syndrome, as per the PCSI (Davies et al., 2020). Some of the issues that caused anxiety in the participants included the inability to remember homework due dates, grades dropping and overthinking their wording in assignments (Davies et al., 2020). The participants who experienced sad or depressive symptoms explained their frustration with the lack of improvement lead to them giving up on their work and ultimately questioning themselves as people (Davies et al., 2020). Some of the participants expressed they fell out with friends and family as they could not mentally deal with having conversations and feeling like they were misunderstood for acting a certain way (Davies et al., 2020). In addition, some of the participants were losing friends due to their irritability. One parent explained her son became angry and paranoid over trivial matters, which was not in his typical nature (Davies et al., 2020). There were mixed responses about the management of post-concussive symptoms at school. Some participants received support such as being offered audio-books, getting extensions and having time off school to recover, whereas other participants felt they did not get any support or it took too long to obtain the support (Davies et al., 2020). The results from this study really highlight the importance of symptom management when returning to school and activities to alleviate emotional and social issues post-concussion. While Davies and colleagues (2020) research identifies specific emotional and social implications a concussion may have on a student returning to school, it is important to recognise how post-concussive symptoms may impact children and adolescents overall quality of life.

***Pediatric Quality of Life when Returning to School***

Research suggests that children and adolescents that experience prolonged concussive symptoms may have negative outcomes in regards to their participation in school and social events, resulting in the reduction of social interactions (Novak et al., 2016). Moran and colleagues (2011) examined how post-concussive symptoms may influence quality of life in children aged 8 to 15 years. Their findings suggest early post-concussive symptoms are a predictor of health related quality of life (HRQOL) in children up to 12 months post-concussion (Moran et al., 2012). Children who presented with more severe initial post-concussive symptoms were more likely to exhibit poorer HRQOL at both 3 months and 12 months post-concussion (Moran et al., 2011). Jones and colleagues (2019) found parents of children and adolescents aged 1 to 15 years old reported improvements in Quality of Life (QoL) within the first 12 months of recovery. Despite the apparent improvement, parents also reported deterioration in their child's QoL between 12 and 48 months, with particular attention to social and school functioning (Jones et al., 2019). Although, a limitation to their research was that the data was collected from parents perspectives of their child's QoL after concussion, with no inclusion of the children's perspectives.

Typically, RTL is best managed through multiple support branches, such as family, health practitioners and school staff. Teachers play a major role in students reintegration period post-concussion. Romm and colleagues (2018) aimed to identify teachers thoughts, feelings and knowledge of concussion to highlight the importance universal guidelines have on school re-integration. Their study found teachers who had experienced a concussion themselves or had their own children who had experienced a concussion, had a better understanding of the recovery process and were more comfortable implementing support strategies (Romm et al., 2018). In comparison, teachers and administration staff who reported minimal involvement with concussion were less informed of the implications a concussion may have on a student's school functioning, as well as the protocols for concussion recovery (Romm et al., 2018). In order to help mitigate potential issues for students returning to school, whether cognitively or socially, it is important to create universal guidelines to help support the needs of the students. The current gaps in the literature regarding return to school guidelines and support after a concussion, warrants the need for further research.

**Pre-existing Learning Conditions**

Some children and adolescents who are diagnosed with a concussion may also be diagnosed with a pre-existing learning condition. Pre-existing learning conditions, particularly Attention Deficit Hyperactivity Disorder (ADHD) and Learning Disability (LD), may influence post-concussion recovery and return-to-learn outcomes (Martin et al., 2022). Learning disabilities, which include Dyslexia, Dyscalculia, Dyspraxia and Dysgraphia, affect approximately 5 to 20 percent of children and adolescents globally (Grigorenko et al., 2020), with ADHD affecting approximately 5.6 to 7.6 percent in children and adolescents globally (Donovan et al., 2019; Salari et al., 2023). Currently, learning assistants (LA) are employed in schools to help assist teachers with children and adolescents with ADHD and learning disabilities in the classroom. Special education aims to alleviate some of the stress that may be placed on teachers and other students, allowing for fewer disruptions daily (Grigorenko et al., 2020).

Despite evidence suggesting special education and support in schools is helpful for children and adolescents with a learning disability or ADHD, there is little understanding of the implications a concussion may add to their school functioning. Martin and colleagues (2022) conducted a study on learning disabilities and ADHD as risk factors for prolonged concussion recovery in children and adolescents. They discovered those diagnosed with LD or ADHD experienced symptoms for a longer duration compared to those without LD or ADHD (Martin et al., 2022). They also identified LD and ADHD to be a factor in delayed recovery, return-to-learn and return to activities (Martin et al., 2022). Although studies have indicated students with a learning disability or ADHD experience symptoms for longer periods, there is little research on symptom management when returning to school for these populations. Therefore, it is imperative to identify symptoms of concussion and how they interact with learning disabilities when returning to school.

**Introduction Summary**

Concussion is a major health concern in pediatric populations. The condition is broadly understood as an injury that disrupts regular brain functioning, resulting from an abrupt external force. Current data shows considerable variation in concussion prevalence, with reports ranging between 2.5 and 25 percent across different populations. The inconsistent prevalence reports highlight the challenges in assessment reporting and individuals not seeking medical treatment.

Post-concussive symptoms manifest across four domains; cognitive, physical, emotional and social. Cognitive symptoms may include attention deficits, memory issues and executive functioning issues. Physical symptoms may include headaches, nausea, dizziness and sleep disturbances. Emotional and social symptoms may include irritability, sadness and anxiety. The post-concussion symptom inventory (PCSI) is the most commonly used tool for assessing symptoms of concussion in Western pediatric populations. While most children and adolescents recover within 3 months, 10 to 33 percent of the population experience persistent post-concussive symptoms. Various factors may influence recovery trajectories such as genetics, concussion history and pre-existing conditions.

School reintegration presents difficulty among children and adolescents. The current return to school guidelines recommends having between 2 and 4 days off school, though the optimal rest duration remains debatable. Research suggests how long the child rests from physical activity and school may determine how long they experience post-concussive symptoms. Furthermore, while initial cognitive rest is beneficial in recovery, prolonged rest may impede it. It is critical to have consistent knowledge of return to school protocols, especially for populations with pre-existing learning conditions, such as students with a learning disability or ADHD. Despite the growing understanding of concussion management, there are still significant gaps in the literature around the interaction of concussive symptoms and pre-existing learning conditions when returning to school. This research aims to address these gaps by examining the relationship between concussion recovery and school functioning in children and adolescents, while controlling for those with pre-existing learning conditions.

**Hypotheses**

This research aims to examine how initial post-concussion symptoms predict school functioning outcomes during the first month following concussion, accounting for pre-existing learning conditions. The research question we will answer is:

1. Does initial post-concussion symptom severity predict school functioning at 1-month post-concussion when controlling for pre-existing learning conditions?

Hypotheses

i. Higher initial post-concussion symptom scores will predict lower school functioning scores at 1 month after controlling for pre-existing learning conditions and demographics.

ii. Pre-existing learning conditions will predict lower school functioning scores at 1-month post-concussion.

# Method

## Participants

We recruited children and adolescents aged 5 to 17 years inclusive between April 2022 and July 2024. We recruited 275 children and adolescents with concussion from five ethnic groups Māori, Pacific, Asian, MELAA/Other and European. Children and adolescents were eligible for recruitment if they were diagnosed with a concussion at any of the following places: Waikato Hospital, Middlemore Hospital, Whangārei Hospital, Waitākere Hospital, Urgent Care and General Practitioner (Lowry et al.) Clinics across South Auckland and Waikato. Self-referrals were also accepted via phone or email for children who received medical attention and were diagnosed with a concussion.

Children and adolescents were eligible if they presented with one or more of the following symptoms: headache, vomiting, feeling mentally foggy, irritability, loss of consciousness, drowsiness or sleep disturbance as a result of a head injury by direct or non-direct force to the head. Children and adolescents were not eligible if, at any time point post-concussion, they received a GCS score of less than 13, indicating a moderate or severe head injury. The exclusion criteria for the study was as follows: neurological intervention or general anaesthesia was needed to manage the injury, the presence of an intracranial injury on a head computerised tomography, evidence of a cerebrospinal fluid leak, the child or adolescent had an intellectual disability that would disrupt completion of the assessments, the injury was non-accidental, the child or adolescent had an insufficient understanding of English to understand the study requirements, multiple traumas had occurred, if there was no clear history of trauma as the primary cause (for example, trauma occurs after a seizure), drug or alcohol use and if the child or adolescent had already completed the study previously.

For ethnicity, children and adolescents identified as either Māori, Pacific, Asian, MELAA/Other and European. For the purpose of this study, we collapsed Asian, MELAA/Other and European into the ethnic category 'non-Māori non-Pacific.' (Table 1). Table 1 further presents the demographic data of the participants sex and age. The mean age of the participants was 12 years old. There were also 18 participants diagnosed with one learning condition, either Learning Disability, ADHD or Dyslexia, and five participants that were diagnosed with two learning conditions. Twenty three participants were diagnosed with having a learning condition, 245 participants did not have a learning condition and seven participants had missing data.

**Table 1.**

*Demographics of Participants (Children & Adolescents)*

| Characteristics | | n | % |
|---|---|---|---|
| Ethnicity | | | |
| | Māori | 78 | 28.4 |
| | Pacific | 36 | 13.1 |
| | Non-Māori Non-Pacific | 161 | 58.5 |
| Sex | | | |
| | Female | 92 | 33.5 |
| | Male | 183 | 66.5 |
| Age | | | |
| | 5-7 years old | 52 | 18.9 |
| | 8-12 years old | 105 | 38.2 |
| | 13-17 years old | 118 | 42.9 |

*Note.* N = number of participants, % = percent

**Ethics**

This study was funded by the Health Research Council (#19-387) and was been approved by the Health and Disabilities Ethics Committee (19/CEN/183).

**Study Design**

The study had five different assessment time points; Timepoint 1 (T1) – preferably between 1 and 4 days post-concussion, but up to 7 days, Timepoint 2 (T2) – 2 weeks post-concussion (plus or minus 6 days), Timepoint 3 (T3) – 1 month post-concussion (plus or minus 6 days), Timepoint 4 (T4) - 3 months post-concussion (plus or minus 14 days) and Timepoint 5 (T5) - 6 months post-concussion (plus or minus 1 month). If T1 was not completed within 7 days, a T2 baseline would be completed which assessed the participant at T2 as well as collecting baseline pre-injury data.

## Measures

### *Demographic information*

At assessment one, parents were asked demographic questions about the child's gender, ethnicity, age and pre-existing health conditions, which included Learning Disability, Attention Deficit Hyperactivity Disorder and Dyslexia.

### *Study Specific Questions*

Both the parent and child questionnaires asked study-specific questions. Parents were asked whether the child had missed any days off school due to the concussion, if so how many, whether the child had returned to school and if so whether it was full time or reduced hours, as well as whether there were any reported escalations in symptoms upon returning to school.

### *Post-Concussion Symptom Inventory*

The Post-Concussion Symptom Inventory was adapted for pediatric populations from the Post-Concussion Scale (Lovell & Collins, 1998), which was initially developed for adults with sports-related concussions. Sady and colleagues (2014) found the scale to be psychometrically reliable with good internal consistency, inter-rater concordance and test-retest reliability, as well as having good convergent validity for each of the four different forms (parent form, adolescents aged 13-17, children aged 8-12 and children aged 5-7). They found the scale to be an appropriate tool to differentiate children and adolescents with a concussion from those without a concussion (Sady et al., 2014).

The PCSI consisted of four subscales representing physical, emotional, cognitive and sleep domains. The scale aimed to identify the severity of the following concussive symptoms. The physical subscale measured headaches, nausea, dizziness, balance problems, visual problems, clumsiness, sensitivity to light, sensitivity to noise and moving more slowly. The emotional subscale measured irritability, sadness, nervousness and feeling more emotional. The cognitive subscale measured difficulty in concentration, difficulty remembering things, feeling confused, feeling mentally foggy and answering slowly. Lastly, the sleep subscale measured fatigue, drowsiness and sleeping more (Sady et al., 2014). There were also five clinical questions with the possible answer of yes or no. On the parent form, the questions were: ‘Has your child complained of dizziness with movement such as riding in a car or when moving their head?’ ‘Has your child complained of feeling lightheaded when they stand up quickly?’ ‘Has your child complained of neck pain or tenderness?’ ‘Has it been harder than usual for your child to fall asleep?’ and ‘Has your child seemed overwhelmed by school’ (Gioia et al., 2019).

This scale was used on both parent and child forms. Parents answered 20 questions regarding the four subscales on a 7-point scale (0 being no problem to 6 being a severe problem), plus answering the question “In general, to what degree is your child acting differently than before the injury (not acting like themselves)?” on a 5-point Likert scale. Adolescents aged 13 to 17 years answered 21 items on a 7-point scale, children aged 8 to 12 years answered 17 items on a 3-point scale and children aged between 5 and 7 years answered 5 items on a 3-point scale. Subscale scores were obtained from all age groups, except for 5 to 7 years due to the small number of items, lower scores indicated fewer symptoms.

Baseline information was collected on the first assessment to obtain information regarding the child’s regular functioning state. During the first assessment both parents and children were asked to rate the child’s symptom severity of the physical, emotional, cognitive and sleep domains pre-injury. The participants were then asked immediately after about their current symptoms post-concussion. It was important to collect the data comparatively to distinguish pre-injury and post-concussion symptoms clearly, as some concussion symptoms, such as headaches, can occur in daily life.

For the purpose of this study, only parent forms were analysed. Total symptom severity scores were calculated by adding together the ratings from all 20 questions on the PCSI parent form. Individual item scores were calculated by summing the individual item scores on each subscale. This study used the PCSI Retrospective-Adjusted Post-concussion Difference (RAPID) scores, which measured any significant changes in symptoms from pre-injury to post-concussion. PCSI RAPID subscale scores were calculated by subtracting the baseline score from the post-concussion score for each of the individual items on each subscale. Each of the item scores were then summed to obtain the final RAPID subscale score for physical, emotional, cognitive and sleep domains. PCSI RAPID total scores were obtained by summing the individual RAPID subscale scores. This process occurred at each timepoint. The PCSI parent report was our primary measure used to classify whether a participant was recovered or symptomatic.

***Pediatric Quality of Life Scale***

The Pediatric Quality of Life Scale (PedsQL) used self-report forms to measure child and adolescents' quality of life. The scale was originally designed using pediatric cancer patients to measure health-related quality of life (HRQOL) (Varni, 1998). The scale has since progressed to a 23-item scale that has been well-documented as valid and reliable (Varni et al., 2003). Internal consistency, test-retest reliability, construct validity and convergent validity have all been demonstrated as good (Varni et al., 2003).

The scale measured across four domains; physical health, emotional functioning, social functioning and school functioning. Physical functioning measured the participants difficulty in walking, running, exercising/doing sport, lifting heavy items, bathing themselves, doing physical jobs and whether they exhibited any hurts or aches and had low energy. Emotional functioning was measured by whether the participants felt afraid or scared, sad, angry, trouble sleeping and worrying about what would happen to them. Social functioning is measured by the child or adolescents problems with getting along with other kids, other kids not wanting to be their friend, other kids teasing them, not being able to do things other kids their age could do and finding it difficult to keep up when playing with other kids. School functioning measured the participants difficulty paying attention in class, forgetting things, trouble keeping up with school work, missing school due to feeling unwell and missing school to go to the doctor or hospital.

There were different versions for each of the age groups: 5 to 7 years, 8 to 12 years and 13 to 18 years, as well as a parent version. Children aged 5-7 years were asked their questions with simplified vocabulary and were provided with a visual scale with a happy face for ‘not feeling that way at all’, a neutral face for ‘feeling that way sometimes’ and a sad face for ‘feeling that way a lot.’ Parents, children aged 8 to 12 years and 13 to 18 years were asked their questions with developmentally appropriate vocabulary on a 5-point Likert scale; Never, Almost Never, Sometimes, Often and Almost Always (Varni, 1998). During school holidays, the school functioning subscale questions were not asked and were therefore not counted in the data during this period. The scale provided the total summary score and individual subscale scores. The total summary score was calculated by firstly reverse coding (what was once a 0 indicating never would be coded as a 4 indicating almost always) and then transforming the items to a 0-100 scale where 0 is equal to 100, 1 is equal to 75, 2 is equal to 50, 3 is equal to 25 and 4 is equal to 0. The total score was the sum of all items (physical, emotional, social and school functioning) divided by the number of items answered on all of the subscales. Individual subscale scores were calculated as a mean score, with the sum of the items from the subscale divided by the amount of items answered on the subscale (Varni, 1998). Children and adolescents with higher scores were indicated to have a better quality of life. For the purpose of this study, we focused on parent reports and for the analyses we used the total PedsQL scores and the PedsQL school functioning subscale scores.

**Procedure**

Potential participants aged 5 to 17 were identified by case screeners doing daily checks of concussion admissions to Waikato and South Auckland urgent care clinics, Waikato Hospital, Middlemore Hospital, Whangārei Hospital, Waitākere Hospital and Waikato and South Auckland GP clinics. A poster was displayed in all emergency department locations to inform potential participants, parents and caregivers of the study, and provided pamphlets for hospital staff to hand out where possible. The poster and pamphlet provided contact details to the potential participants if they chose to opt-out within 24 hours. They could text, call or email stating they did not wish to be contacted or participate in the study.

The research nurse then completed a case screening form for each child diagnosed with a concussion. The research nurse confirmed whether the participants met the inclusion criteria and checked if they had opted out of the study. The potential participants and parents were then contacted by the research nurse to see if they were interested in the study, the research nurse following a provided script. The call script included an explanation of who we were, why they were being contacted, a summary of what the study entailed, checking they were eligible upon their confirmation and finally booking their first interview. Checking the eligibility included asking the following questions: *'What date did they have the concussion,' 'Did they have any other injuries,' 'If yes, what was the other most severe injury.'* If the child obtained a severe injury that required general anaesthetic they were not eligible to take part in the study. The participant and parent were then booked in a suitable time to complete the first of five assessments. The first assessment needed to be completed within 14 days post-concussion, although within the first 7 days was preferable. Assessments could take place on zoom, over the phone or in person. Each case was assigned to the RA who remained the primary contact for the child and parent for the remainder of the study.

The RA emailed new participants and parents the information sheet as well as a reminder text message the day before each assessment confirming their attendance. If needed, the appointments were rescheduled. During the first assessment, the RA went through the information sheet with both the parent and child. The main points covered were: study description, the purpose of the study, what participation in the study involved, possible benefits and risks of the study, finance involved with the study, the rights as a study participant, information if they choose to stop in the middle of the study and contact information for the study. The RA then gained written consent from both the parent and child over 16 years, and written assent from the child under 16 years. All forms for the study were completed with Qualtrics offline app.

The first assessment was estimated between 30 minutes to 1 hour due to the extra information needed, each subsequent assessment taking around 30 minutes. If the participants responses exceeded the pre-determined clinical cut-off scores for the PCSI or PedsQL scales, the RA sought permission to notify the participant and parents GP. Lastly, the RA would ask the participant which store they would like to receive their $20 voucher from; The Warehouse or PAK'n'SAVE. The RA would then open it up to the participants for any questions or concerns before booking the next assessment with the participant.

**Data Analysis**

First, the data was exported from Qualtrics to SPSS for quantitative analysis.

The statistical file consisted of parent data from the PCSI (baseline, T1, T2 and T3), PedsQL total scores and school functioning subscale scores (T1, T2, T3), demographics and study-specific school related questions. The data was organised by participant ID.

A new variable was computed using each of the three learning condition variables (ADHD, Learning Disability and Dyslexia) to identify whether a child had any type of learning condition or not. Ethnicity was dummy coded and collapsed into three groups; Māori, Pacific and non-Māori non-Pacific. Participants who had indicated they had returned to school either part-time or full-time were asked if any symptoms had worsened upon returning, which was then scored as either yes or no. A new variable was computed to include the total number of days absent from school between assessment one and assessment three. For the purpose of this study we only analysed the RAPID scores from assessment one. As some participants started at T2, a new variable was computed as 'PCSI RAPID assessment one' which included PCSI RAPID scores from T1 and PCSI RAPID scores from participants who started their first assessment at T2.

This research aimed to examine whether initial PCSI post-concussive symptoms predicted PedsQL school functioning outcomes at 1 month post-concussion, accounting for pre-existing learning conditions. First, the data was checked through descriptive statistics to identify any outliers or missing data. We examined our samples return to school status plus any symptoms they were experiencing upon returning to school at 1 month post-concussion. We also produced the mean scores for school functioning, initial symptom severity and overall functioning by learning condition to establish any differences that might inform subsequent analyses.

Next, we conducted chi-square tests to examine the association between ethnicity, sex and learning condition prevalence. We further compared children with and without a learning condition across initial PCSI RAPID scores, PedsQL school functioning scores at 1 month post-concussion, initial PCSI cognitive and emotional subscale scores and age. These analyses were examined to address our second hypothesis in regards to the impact pre-existing learning conditions may have on a child's school functioning at 1 month post-concussion.

To address our research question, we conducted Pearson's correlations to explore the relationships between our primary predictor (initial PCSI RAPID scores) and outcome variable (PedsQL school functioning scores 1 month post-concussion). This also included looking at the associations between specific RAPID subscale scores of the PCSI (cognitive and emotional) and our outcome variable that may have been relevant to school functioning. We also looked at the association between age and school functioning at 1 month post-concussion. We further examined the association between the total number of days absent from school between T1 and T3 and initial PCSI RAPID scores, as well as overall PedsQL scores at 1 month post-concussion.

Finally, we conducted a hierarchical multiple linear regression to test our main hypothesis. We systematically controlled for demographics in step one, adding learning condition presence to step two, with initial PCSI RAPID scores in step three to determine if initial PCSI symptom severity predicted school functioning outcomes at 1 month post-concussion, accounting for learning conditions and demographics.

# Results

## Participant Survey Scores by Learning Conditions

First, we calculated the mean PCSI RAPID scores, PCSI RAPID emotional and cognitive subscale scores at assessment one, the PedsQL school functioning scores at 1 month post-concussion and the total PedsQL scores 1 month post-concussion by children who were diagnosed with a learning condition or not (Table 2). The means for the overall sample for each variable is presented in the last column. On average, children with learning conditions had poorer school functioning scores at 1 month post-concussion compared to children without a learning condition. Similarly, total PedsQL scores 1 month post-concussion were lower for children with a learning condition compared to those without. The mean initial PCSI RAPID scores were similar between children with and without a learning conditions, suggesting both groups had comparable symptom severity initially, regardless of learning condition presence. Both groups also had similar mean scores on the PCSI RAPID subscales, with cognitive symptoms being more prominent than emotional symptoms initially. The data suggests that pre-existing learning conditions may influence pediatric quality of life rather than initial symptom severity.

**Table 2.**

*Summary of the Mean Symptom Severity and Quality of Life Scores by Learning Condition Presence*

| | Learning Condition | | | | | |
|---|---|---|---|---|---|---|
| Scales | Has a learning condition | | Has no learning condition | | Total | |
| | *M* | SD | *M* | SD | *M* | SD |
| PedsQL school functioning scores | 78.16 | 25.51 | 82.68 | 19.79 | 82.18 | 20.46 |
| *N* | 19 | | 152 | | 171 | |
| PedsQL total scores | 84.55 | 18.78 | 87.36 | 14.01 | 87.08 | 14.53 |
| *N* | 20 | | 178 | | 198 | |
| PCSI RAPID scores | 27.43 | 21.83 | 27.09 | 22.32 | 27.12 | 22.23 |
| *N* | 21 | | 226 | | 247 | |
| PCSI RAPID emotional subscale scores | 4.0 | 4.70 | 4.50 | 4.60 | 4.50 | 4.60 |
| *N* | 21 | | 226 | | 247 | |
| PCSI RAPID cognitive subscale scores | 6.70 | 7.50 | 5.90 | 6.80 | 6.0 | 6.80 |
| *N* | 21 | | 226 | | 247 | |

*Note. M* = Mean, SD = Standard Deviation, *N* = number of respondents. Scores are rounded to two decimal places.

**Learning Condition Comparisons: Initial Symptoms, School Functioning and Demographics**

Next, we conducted chi square tests of independence to examine if there were demographic differences in those with and without a learning condition. Both sex and ethnicity were not significantly associated with having a learning condition.

We then conducted an independent samples t-test to investigate if there were differences in age among children with and without a learning condition. The analysis revealed the mean age of children with a learning condition to be slightly older than those without a learning condition, although this difference was not statistically significant (Table 3).

Finally, we conducted independent t-test's to further investigate if there were significant group differences in initial total PCSI RAPID scores and initial cognitive and emotional PCSI RAPID scores among those with and without a learning condition. On average, participants with and without a learning condition had similar initial PCSI RAPID scores at assessment one that were not significant, with a mean difference of .34. Furthermore, the analysis revealed no statistically significant differences in initial PCSI RAPID cognitive subscale scores or emotional subscale scores between children with and without a learning condition (Table 3).

**Table 3.**

*Group Comparisons by Learning Condition Presence*

| | Has learning condition | | No learning condition | | *t*(df) | *p* | Cohen's |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | | | *d* |
| PedsQL school functioning scores | 78.16 | 25.5 | 82.68 | 19.79 | .75(169) | .46 | .22 |
| Initial PCSI total RAPID scores | 27.43 | 21.83 | 27.09 | 22.32 | -.07(245) | .95 | .009 |
| Initial PCSI RAPID emotional | 4.0 | 4.71 | 4.48 | 4.60 | .46(245) | .65 | .11 |
| Initial PCSI RAPID cognitive | 6.6 | 7.54 | 5.90 | 6.76 | -.49(245) | .62 | -.11 |
| Age | 13.0 | 2.86 | 11.23 | 3.54 | -2.33(266) | .26 | -.51 |

*Note:* Significance is at .05 (two-sided).

**Return to School Patterns**

We then calculated how many children had returned to school at 1 month post-concussion, with 11 participants not yet returned (4.0 percent), 14 participants returned with reduced hours (5.1 percent), and 187 participants returned full time (68.0 percent). There was missing data for 63 participants at Timepoint 3 (22.9 percent). Of the 275 participants, 83 participants had at least 1 day of school absence between their initial assessment at 1-4 days post-concussion (T1) and 1 month post-concussion (T3) (30.2 percent) with 46 of these participants having more than 2 days absence from school (16.7 percent). Of the participants who indicated they had returned to school either full-time or part-time at assessment three (1 month post-concussion), 49 were experiencing the exacerbation of at least one symptom. The most common symptoms of concussion upon returning to school were headaches (20 participants, 7.3 percent) and feeling tired (25 participants, 9.1 percent).

We wanted to further investigate if the total number of days absent from school at 1 month was associated with a child's overall PedsQL score by 1 month post-concussion and their initial PCSI RAPID scores. First, the total number of school days absent by 1 month post-concussion revealed a significant positive moderate association with initial PCSI RAPID scores, $r = .48$, $p < .001$. This suggests that more severe initial PCSI RAPID scores were associated with having more school absence days. Next, the total number of school days absent by 1 month post-concussion had a significant negative moderate association with a child's overall PedsQL score at 1 month post injury, $r = -.48$, $p < .001$. This suggests as the number of days absent from school increases, overall pediatric quality of life worsens at 1 month post injury.

**Relationships Between school Functioning, Initial Symptom Severity and Age**

We first wanted to investigate the relationship between a child's age and their PedsQL school functioning scores 1 month post-concussion and their initial PCSI RAPID scores. First, a child's age was not significantly associated with their school functioning scores 1 month post-concussion, *r* = -.12, *p* = .13. Although, we found a child's age had a significant positive weak association with initial PCSI RAPID scores, *r* = .18, *p* = .003. This suggests the older a child was, the more severe their initial PCSI RAPID scores were.

We then focused on our primary research question, to examine whether initial PCSI RAPID scores were associated with PedsQL school functioning scores at 1 month post-concussion. It is important to note that higher scores on the PCSI represented more severe symptoms and higher scores on the PedsQL represented better school functioning. Pearson's correlation revealed a moderate negative association between initial PCSI RAPID scores and school functioning scores 1 month post-concussion, *r* = -.31, *p* <.001. This suggests that as PCSI symptom severity scores worsen a child's PedsQL school functioning scores also worsen.

Associations between initial PCSI RAPID cognitive and emotional subscale scores and PedsQL school functioning scores 1 month post-concussion were also investigated. First, Pearson's correlation revealed a significant weak negative association between school functioning scores 1 month post-concussion and initial PCSI RAPID cognitive scores, *r* = -.29, *p* <.001. This suggests, as PCSI cognitive symptom severity worsens, school functioning scores also worsen. Lastly, initial PCSI RAPID emotional scores revealed a significant weak negative association with a child's school functioning at 1 month post-concussion, *r* = -.20, *p* = .009. This suggests as PCSI emotional symptom severity worsens, school functioning scores also worsen.

**Predictors of School Functioning Outcomes: Initial Symptom Severity and Demographics**

Finally, a hierarchical multiple linear regression was conducted to investigate our main research question, whether initial PCSI symptom severity would predict school functioning outcomes at 1 month post-concussion, while controlling for demographics and learning conditions. The predictor variables were chosen based on our main research question and hypotheses, as well as research from past studies. The predictors were added in three different blocks as presented in Table 4. The final model was significant, and explained 12 percent of the variance in school functioning scores ($R^2$ = .12, F(6, 158) = 3.53, $p$ = .003).

The first block contained demographic predictors, sex (male or female), age (5-17 years) and ethnicity (non-Māori non-Pacific was the comparison group), characteristics that previous research has shown may influence school functioning. The second block contained whether a participant had the presence of a learning condition or not. The third and final block included the total PCSI RAPID scores at assessment one, which had shown moderate negative correlations with school functioning outcomes at 1 month post-concussion from the Pearson's correlation.

Demographics (sex, age and ethnicity) did not significantly predict school functioning outcomes ($R^2$ = .02, F(4, 160) = .90, $p$ = .46). Adding learning conditions to the model did not significantly predict school functioning outcomes ($R^2$ = .02, F(5, 159) = .77, $p$ = .58). Although, adding initial PCSI symptom severity to the model significantly improved prediction.

Initial PCSI symptom severity was the only significant predictor in the final model, indicating that higher initial PCSI symptom severity predicted poorer school functioning outcomes at 1 month post-concussion. For our secondary hypothesis, learning conditions did not significantly predict school functioning outcomes.

**Table 4.**

*Hierarchical Multiple Linear Regression Analysis of Predictors of School Functioning at 1 Month Post-Concussion*

| | Unstandardized coefficients | 95% CI | | Std. Error | Standardized Coefficients | Sig. |
|---|---|---|---|---|---|---|
| | *B* | LB | UB | *SE B* | *β* | *p* |
| **Step 1** (Constant) | 90.65 | 76.91 | 104.394 | 6.96 | | <.001 |
| Age | -.85 | -1.77 | .07 | .47 | -.14 | .07 |
| Māori | 1.69 | -5.22 | 8.60 | 3.50 | .04 | .63 |
| Pacific | -.45 | -10.44 | 9.54 | 5.06 | -.01 | .93 |
| Sex | .47 | -6.20 | 7.14 | 3.38 | .01 | .89 |
| **Step 2** (Constant) | 90.44 | 76.64 | 104.25 | 6.99 | | <.001 |
| Age | -.80 | -1.75 | .14 | .48 | -.14 | .09 |
| Māori | 1.62 | -5.31 | 8.56 | 3.51 | .04 | .64 |
| Pacific | -.63 | -10.67 | 9.41 | 5.10 | -.01 | .90 |
| Sex | .46 | -6.25 | 7.17 | 3.40 | .01 | .89 |
| Learning Condition | -2.58 | -13.06 | 7.89 | 5.30 | -.04 | .63 |
| **Step 3** (Constant) | 94.54 | 81.23 | 107.85 | 6.74 | | <.001 |
| Age | -.62 | -1.53 | .29 | .46 | -.10 | .18 |
| Māori | 2.29 | -4.33 | 8.90 | 3.35 | .05 | .50 |
| Pacific | 1.41 | -8.22 | 11.03 | 4.87 | .02 | .77 |
| Sex | 1.08 | -5.30 | 7.46 | 3.23 | .03 | .74 |
| Learning Condition | -3.03 | -13.01 | 6.96 | 5.06 | -.05 | .55 |
| Initial PCSI score | -.28 | -.41 | -.14 | .07 | -.31 | <.001 |

*Note.* $R^2$ = .02 for Model 1; $\Delta R^2$ = .03 for Model 2; $\Delta R^2$ = .12 for Model 3. Reference group for ethnicity is non-Māori non-Pacific.

## Discussion

Concussion symptoms can be a significant issue for children and adolescents when trying to re-integrate back to school. Currently, return-to-school guidelines vary, which results in inconsistent support after concussion (Wan & Nasr, 2020). Therefore, it is of interest to identify symptoms experienced after concussion and their severity and how they may impact a child when returning to school. This study aimed to examine how initial post-concussion symptom severity predicted school functioning outcomes during the first month following a concussion in children and adolescents aged 5-17 years, while accounting for pre-existing learning conditions. Our primary hypothesis was that higher initial post-concussion scores would predict lower school functioning scores at 1 month post-concussion, while controlling for pre-existing learning conditions and demographics. Our secondary hypothesis was that pre-existing learning conditions would predict lower school functioning scores at 1 month post-concussion.

### Initial Symptom Severity as a Predictor of School Functioning (Aim 1)

Our main hypothesis was supported by the study's findings. Initial symptom severity, measured by the PCSI RAPID scores, was the only significant predictor of school functioning outcomes at 1 month post-concussion, as shown from the hierarchical multiple linear regression analysis. The final model explained 12 percent of the variance in school functioning scores. Demographics and having a learning condition were not significant predictors. The results from the analysis suggested that participants with more severe initial symptoms were associated with poorer school functioning outcomes at 1 month post-concussion.

The finding that initial PCSI RAPID scores was a predictor for school functioning outcomes in the final model aligns with existing literature about the influence post-concussive symptoms has on pediatric quality of life (Moran et al., 2016). The moderate negative correlation ($r$ = -.31) between initial symptom severity and school functioning scores suggests that children and adolescents that are presenting with more severe symptoms are having greater difficulties at school 1 month post-concussion. However, this relationship only accounts for a small amount of the variance in school functioning scores, which indicates other factors are also playing a role. This relationship provides critical insight for the need for appropriate symptom management guidelines in the acute phase of concussion. This is particularly important in the context of individual developmental needs post-concussion. Ages 5-17 years are critical for cognitive, social and school development (Schneider et al., 2016). Disruption to the quality of life domains may negatively impact children and adolescents' education beyond 1 month post-concussion. Previous research reported deterioration in pediatric QoL between 12-48 months post-concussion (Jones et al., 2019). Although, like our study, Jones and colleagues (2019) explicitly used parent reported data, which may not be as reliable as using child and adolescent reports as well. Moreover, the negative correlation between initial symptom severity and school functioning at 1 month post-concussion suggests early identification of symptoms and their severity could serve as a crucial indicator for early educational accommodations.

We further examined the relationship between specific subscales on the PCSI (cognitive and emotional) and school functioning outcomes. The correlations revealed that both the initial PCSI emotional subscale ($r$ = -.20) and cognitive subscale ($r$ = -.29) were significantly associated with school functioning at 1 month post-concussion. The slightly stronger association between cognitive symptoms and school functioning aligns with current literature, as cognitive disruptions have been reported as a primary concern when returning to school after a concussion (Schneider et al., 2016). It is important to note that the variance explained from the regression is still low, however the relationship between these variables informs which symptoms are most closely related to school functioning. Some of the key cognitive symptoms assessed by the PCSI are difficulties in concentration, difficulty remembering things and becoming confused with directions or tasks. This aligns with previous research that these symptoms have been closely linked with school functioning (Schneider et al., 2016). Furthermore, these symptoms create difficulties in the classroom such as unable to maintain attention to complete tasks, unable to process and retain new information and unable to manage their time accordingly (Schneider et al., 2016). The negative association between cognitive symptoms and school functioning outcomes is consistent with the literature and is what we would expect to see.

Whilst the association between emotional symptoms and school functioning was somewhat weaker, it remains statistically significant. Our results align with previous research that emotional symptoms such as irritability and sadness can impact a child's school functioning (Davies et al., 2020). Experiencing such symptoms may cause difficulties in the classroom such as participating in activities and discussions, as well as generally managing the demands school places on a child socially. As Davies and colleagues (2020) study suggested, it is crucial for students to receive adequate support upon returning to school, to alleviate some of the stressors that may occur. The significant correlations from both subscales reveals the complex nature of post-concussion symptoms and how they may impact a child when returning to school. Particularly at school, the overlap between cognitive and emotional symptoms of concussion may be more evident. Cognitive difficulties such as difficulty remembering things may lead to increased frustration and irritability which in turn may further worsen cognitive ability (Davies et al., 2020). The interconnection between the two symptom domains demonstrates the need for comprehensive support accommodations upon returning to school post-concussion.

Importantly, age was not correlated with school functioning at 1 month post injury. While age was positively associated with initial symptom severity, it appears to not predict school functioning outcomes. However, the number of days absent from school was significantly correlated with both initial symptom severity and overall quality of life. This association suggests that children with more severe concussive symptoms not only portray poorer school functioning outcomes, but also demonstrate this through behaviours such as missing school. Recognising school absence patterns can provide insight into how concussion symptoms manifest in naturalistic settings, rather than solely relying on self-report measures. The recommended number of days off of school is 1-2 days in New Zealand (Accident Compensation Corporation, 2011), with current guidelines advising parents to follow guidance from health professionals based on the needs of the child or adolescent (Ministry of Education, 2025). While most of our participants had returned to school fulltime by 1 month, there was a high number of children that had more than the recommended number of school absence days. The average number of school absence days in our study between assessment one and assessment three was 5 days. There were 46 children who had more than the recommended number of days absent from school in New Zealand, revealing concussion recovery and return-to-school is non-linear. The discrepancy between recommended school absence duration and actual school absence patterns, highlights how concussion recovery is individualised and therefore needs to be considered when advising appropriate return-to-school protocols.

**Pre-existing Learning Conditions and Post-Concussion School Functioning (Aim 2)**

The secondary aim of this study was to assess whether pre-existing learning conditions predicted school functioning outcomes at 1 month post-concussion. Few studies have examined how learning conditions may impact school functioning after a concussion. However, the results from the hierarchical regression analysis did not support this hypothesis. The presence of a learning condition did not significantly predict school functioning outcomes at 1 month post-concussion, despite Martin and colleagues (2022) study suggesting specific learning conditions (LD and ADHD) to be a factor in delayed recovery and return-to-learn.

However, further analysis indicated additional insight for these unexpected results. We found no significant differences between children who had a learning condition or not and their initial symptom severity, which included emotional and cognitive symptoms. This finding indicates that children with and without learning conditions present similar symptom severity following a concussion, which may partially explain why learning condition presence did not predict outcomes of school functioning in the regression model. Moreover, the findings suggested that quality of life related to school functioning is similar in children with and without learning conditions.

Our secondary hypothesis may not have been supported due to the large sample imbalance between having a learning condition (n = 23) and not (n = 245). This may have impacted the statistical power of the analysis from detecting any meaningful effects. Martin and colleagues (2022) examined learning conditions as a risk factor for prolonged concussion recovery in children. Their sample had 680 participants, with 177 participants having a learning condition (Martin et al., 2022). The results from their study revealed participants with a learning condition were significantly associated with delayed return-to-school and symptom recovery (Martin et al., 2022). Additionally, the results from their study further support that our findings may be due to sample imbalance rather than a true absence of effect. Our study focused on outcomes at 1 month, which may not have been long enough to identify how learning conditions might moderate the impact concussion symptoms have on school functioning. Previous research suggests those diagnosed with a learning condition experience concussion symptoms for longer periods of up to 12 months (Martin et al., 2022). Therefore, it would be recommended that longer-term follow up assessments may be necessary to fully understand the interaction between learning conditions and school functioning.

This study has provided knowledge of concussion recovery in New Zealand children and adolescents, addressing the gap around school functioning after concussion in pediatric populations. Contrary to previous research, we found children with learning conditions did not present with more severe initial post-concussion symptoms, nor did learning conditions predict poor school functioning outcomes at 1 month post injury. This challenges the current literature that pre-existing learning conditions are likely to predispose children to more severe acute concussion symptoms and poorer school functioning outcomes. Although initial symptom severity accounted for only a small variance in school functioning, this study provides foundational work for future research examining specific concussion symptoms and specific domains of school functioning that may be impacted.

**Strengths**

A significant strength of this research was using a longitudinal repeated measures design. Although using the 1 month follow up assessment could be potentially limiting for long-term understanding, it captured a crucial period of concussion recovery. As previous research suggested, most children and adolescents return to school full time within 2-4 days post-concussion (Kemp & O'Brien, 2022). This study was able to capture time relevant data to inform early intervention and support planning. Furthermore, the findings offer practical guidance to educational and healthcare providers to create inclusive support plans for children returning to school post-concussion.

Furthermore, a strength of this study was that it captured baseline data to distinguish the participants symptoms from pre to post-concussion. The inclusion of pre-injury baseline data allowed for the examination of symptom severity to be relative to the individual participant, to recall how they usually felt prior to injury, rather than relying solely on post-concussion reports. The within-subjects comparison allowed for individual differences in symptom reporting and developmental variations. Calculating the change in symptom scores can be particularly valuable for children diagnosed with a pre-existing learning condition, where their baseline symptoms may vary considerably compared to those without a learning condition.

Another strength of the study was the diversity in demographics. This included an adequate ethnic representation of Māori (n = 78), Pacific (n = 36) and non-Māori non-Pacific (n = 161). The diversity in ethnic groups strengthens the generalizability of our findings across different cultural populations. Moreover, our sample had a broad age range (5-17) which provided strength to the study, obtaining the various effects concussion may have at different developmental periods throughout childhood. Furthermore, this research provided changes in many different areas of well-being including emotional, cognitive and school functioning, making the findings broadly applicable to pediatric concussion populations.

**Limitations**

While the study had an overall substantial number of participants at the first assessment, missing data at various timepoints presents as an important limitation. The reduction from 275 participants to 252 in initial PCSI RAPID scores, then the further reduction to 193 for PedsQL school functioning scores at T3, raises the concern of potential sample biases. The missing data could have been due to various reasons such as participants dropping out of the study by T3, participants being on school holiday during their T3 assessment or intentional omissions. This could then lead to the sample not being an accurate representation or generalisable to the broader population. Furthermore, we did not have participants baseline data on school functioning prior to concussion. This has implications that include not being able to measure true recovery. Without a baseline, it is unknown what the child's prior school functioning was like which may therefore lead to the overestimation of how concussion symptoms impact school functioning.

Another important limitation of the study was the sole use of parent reports. This particularly raises concerns on the reporting of symptoms on the PCSI, as well as reporting how their child is finding school. While parents reporting for young children (ages 5-7) is typically considered developmentally appropriate, due to limitations in the child's self-report capabilities (Sady et al., 2014), the problem becomes more prominent in older children and adolescents that have a better understanding of their symptoms and how to report them. Relying exclusively on parent reports limits comprehensive symptom assessment, as it becomes more difficult to capture the child and adolescents subjective symptoms. Moreover, internal symptoms, such as headaches and cognitive difficulties, can be difficult to observe which in turn may limit accurate representation of symptom severity. Using child reports is recommended for future studies.

Although this study focused on a critical period of concussion recovery, the full trajectory of school functioning past 1 month post-concussion was not investigated. This study did not account for children who experienced poor school functioning outcomes beyond this timeframe. The examined timeframe may be particularly limiting for understanding the impact persistent post-concussion symptoms may have on school functioning outcomes. As the typical recovery timeframe from concussion is between 1 week and 3 months, this study did not account for those who may have experienced persistent post-concussion symptoms beyond 3 months, and the potential impact PPCS may have had on their school functioning. Furthermore, pre-existing learning conditions may have had a more notable impact on school functioning beyond 1 month post-concussion.

## Conclusions and Recommendations

In conclusion, this research provides important evidence that early symptom assessment is helpful for understanding school functioning outcomes after concussion across pediatric populations. Our findings support our main hypothesis that initial post-concussion symptom severity predicts school functioning at 1 month post-concussion, but did not support our second hypothesis regarding the predictive nature of pre-existing learning conditions. The results show significant implications for both education and healthcare providers, informing the need for comprehensive assessment during the acute phase post-concussion and adequate support guidelines for children returning to school. Our findings suggest that children presenting with more severe symptoms initially may benefit from specific support plans that are catered to their individuals needs upon returning to school. Educators should work closely with healthcare providers during the acute phase of concussion, aiming to having a thorough understanding of concussive symptoms and how they may impact a child's school functioning.

It is recommended that future studies would examine school functioning beyond the 1 month recovery period to determine whether acute symptom severity explains more variance in school functioning outcomes as time progresses. Future research would include school functioning data between 6 months and 12 months post-concussion to provide valuable insight about pediatric quality of life. As pre-existing learning conditions and age were not significant predictors of school functioning at 1 month, it would be interesting to examine whether their predictive nature changes as children progress through the school year and the demands of school increase. Furthermore, it would be beneficial to examine children with persistent post-concussion symptoms from 6 months and whether PPCS predicts school functioning outcomes. Moreover, exploring what specific aspects of school functioning were problematic for the child would also be beneficial for creating individualised support plans. Teacher reports should also be investigated to examine a different perspective of how children and adolescents behave in regards to a classroom setting.

As stated in the limitations, it can be difficult for parents to observe particular behaviours accurately in relation to school functioning. It is recommended that future studies address the limitation of solely using parent reports, by including child reports of all ages and parent reports to identify any variance in parent-child and parent-teacher concordance. This could provide a more comprehensive assessment of symptom severity and school functioning outcomes. Furthermore it is recommended that future studies examine a sample that is more balanced in regards to children with pre-existing learning conditions. As formerly mentioned, the small number of participants with a learning condition may have impacted the statistical power to detect effects in the sample. Future research would examine a larger sample that includes more participants with learning conditions, as well as examining participants with different learning conditions such as dyscalculia, dyspraxia and dysgraphia.

Whilst there were limitations to this study, particularly the small sample of children with learning conditions and the reliance of parent reports, it provides foundational data for future research on school functioning outcomes post-concussion. Our findings support the continued examination of concussion symptom severity and how this may impact a child when returning to school. Furthermore, this research contributes to the growing body of literature, emphasizing the need for targeted support guidelines to improve school functioning outcomes across developmental stages after concussion.

# Bibliography

Accident Compensation Corporation. (2011). *Caring for your child after their head injury*. Retrieved from https://www.acc.co.nz/assets/im-injured/9a24662804/ACC6009-Caring-for-your-child-after-their-head-injury.pdf

Araujo, G. C., Antonini, T. N., Monahan, K., Gelfius, C., Klamar, K., Potts, M., Yeates, K. O., & Bodin, D. (2014). The relationship between suboptimal effort and post-concussion symptoms in children and adolescents with mild traumatic brain injury. *The Clinical Neuropsychologist*, *28*(5), 786-801.

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.

Babikian, T., Satz, P., Zaucha, K., Light, R., Lewis, R. S., & Asarnow, R. F. (2011). The UCLA longitudinal study of neurocognitive outcomes following mild pediatric traumatic brain injury. *Journal of the International Neuropsychological Society*, *17*(5), 886-895.

Balalla, S., Krägeloh, C., Medvedev, O., & Siegert, R. (2020). Is the Rivermead post-concussion symptoms questionnaire a reliable and valid measure to assess long-term symptoms in traumatic brain injury and orthopedic injury patients? A novel investigation using Rasch analysis. *Neurotrauma Reports*, *1*(1), 63-72.

Blume, H. K. (2015). Headaches after concussion in pediatrics: a review. *Current pain and headache reports*, *19*(9), 42.

Breck, J., Bohr, A., Poddar, S., McQueen, M. B., & Casault, T. (2019). Characteristics and incidence of concussion among a US collegiate undergraduate population. *JAMA network open*, *2*(12), e1917626-e1917626.

Brown, N. J., Mannix, R. C., O'Brien, M. J., Gostine, D., Collins, M. W., & Meehan, W. P., 3rd. (2014). Effect of cognitive activity level on duration of post-concussion symptoms. *Pediatrics*, *133*(2), e299-304. https://doi.org/10.1542/peds.2013-2125

Cancelliere, C., Coronado, V. G., Taylor, C. A., & Xu, L. (2017). Epidemiology of isolated versus nonisolated mild traumatic brain injury treated in emergency departments in the United States, 2006-2012: sociodemographic characteristics. *The Journal of Head Trauma Rehabilitation*, *32*(4), E37-E46.

Carroll, L. J., Cassidy, J. D., Holm, L., Kraus, J., Coronado, V. G. (2004). Methodological issues and research recommendations for mild traumatic brain injury: the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *J Rehabil Med*, *43*, 113-125.

Catale, C., Marique, P., Closset, A., & Meulemans, T. (2009). Attentional and executive functioning following mild traumatic brain injury in children using the Test for Attentional Performance (TAP) battery. *Journal of clinical and experimental neuropsychology*, *31*(3), 331-338.

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. e132.

Cheng, J., Ammerman, B., Santiago, K., Jivanelli, B., Lin, E., Casey, E., & Ling, D. (2019). Sex-based differences in the incidence of sports-related concussion: systematic review and meta-analysis. *Sports health*, *11*(6), 486-491.

Cnossen, M. C., van der Naalt, J., Spikman, J. M., Nieboer, D., Yue, J. K., Winkler, E. A., Manley, G. T., Von Steinbuechel, N., Polinder, S., & Steyerberg, E. W. (2018).

Prediction of persistent post-concussion symptoms after mild traumatic brain injury. *Journal of neurotrauma*, *35*(22), 2691-2698.

Davies, S. C., Bernstein, E. R., & Daprano, C. M. (2020). A qualitative inquiry of social and emotional support for students with persistent concussion symptoms. *Journal of Educational and Psychological Consultation*, *30*(2), 156-182.

Dharsee, S., Laliberté Durish, C., Tang, K., Brooks, B. L., Noel, M., Ware, A. L., Beauchamp, M. H., Craig, W., Doan, Q., & Freedman, S. B. (2024). Association of psychological resilience, cognitive reserve, and brain reserve with post-concussive symptoms in children with mild traumatic brain injury and orthopedic injury: An A-CAP Study. *Journal of neurotrauma*.

Donovan, G. H., Michael, Y. L., Gatziolis, D., Mannetje, A. t., & Douwes, J. (2019). Association between exposure to the natural environment, rurality, and attention-deficit hyperactivity disorder in children in New Zealand: a linkage study. *The Lancet Planetary Health*, *3*(5), e226-e234.

Dufour, S. C., Adams, R. S., Brody, D. L., Puente, A. N., & Gray, J. C. (2020). Prevalence and correlates of concussion in children: Data from the Adolescent Brain Cognitive Development study. *Cortex*, *131*, 237-250.

Eisenberg, M. A., Meehan III, W. P., & Mannix, R. (2014). Duration and course of post-concussive symptoms. *Pediatrics*, *133*(6), 999-1006.

Feigin, V. L., Theadom, A., Barker-Collo, S., Starkey, N. J., McPherson, K., Kahan, M., Dowell, A., Brown, P., Parag, V., & Kydd, R. (2013). Incidence of traumatic brain injury in New Zealand: a population-based study. *The Lancet Neurology*, *12*(1), 53-64.

Gioia, G. A. (2016). Medical-school partnership in guiding return to school following mild traumatic brain injury in youth. *Journal of child neurology*, *31*(1), 93-108.

Gioia, G. A., Vaughan, C. G., & Sady, M. D. (2019). *Post Concussion Symptom Inventory-2 (PCSI-2)*.

Giromini, L., Young, G., & Sellbom, M. (2022). Assessing negative response bias using self-report measures: New articles, new issues. *Psychological Injury and Law*, *15*(1), 1-21.

Grigorenko, E. L., Compton, D. L., Fuchs, L. S., Wagner, R. K., Willcutt, E. G., & Fletcher, J. M. (2020). Understanding, educating, and supporting children with specific learning disabilities: 50 years of science and practice. *American Psychologist*, *75*(1), 37.

Haarbauer-Krupa, J., Lebrun-Harris, L. A., Black, L. I., Veliz, P., Daugherty, J., Desrocher, R., Schulenberg, J., Pilkey, D., & Breiding, M. (2021). Comparing prevalence estimates of concussion/head injury in US children and adolescents in national surveys. *Annals of epidemiology*, *54*, 11-20.

Halstead, M. E., McAvoy, K., Devore, C. D., Carl, R., Lee, M., Logan, K., Medicine, C. o. S., Fitness, Health, C. o. S., Brenner, J. S., & Demorest, R. A. (2013). Returning to learning following a concussion. *Pediatrics*, *132*(5), 948-957.

Hon, K. L., Leung, A. K., & Torres, A. R. (2019). Concussion: a global perspective. Seminars in pediatric neurology,

Jones, K. M., Prah, P., Starkey, N., Theadom, A., Barker-Collo, S., Ameratunga, S., Feigin, V. L., & Group, B. S. (2019). Longitudinal patterns of behavior, cognition, and quality of life after mild traumatic brain injury in children: BIONIC study findings. *Brain injury*, *33*(7), 884-893.

Junn, C., Bell, K. R., Shenouda, C., & Hoffman, J. M. (2015). Symptoms of concussion and comorbid disorders. *Current pain and headache reports*, *19*, 1-8.

Kazl, C., & Torres, A. (2019). Definition, classification, and epidemiology of concussion. Seminars in pediatric neurology,

Kemp, A. M., & O'Brien, K. H. (2022). Critical elements of return to learn for students with concussion: A scoping review. *The Journal of Head Trauma Rehabilitation*, *37*(2), E113-E128.

Lal, A., Kolakowsky-Hayner, S. A., Ghajar, J., & Balamane, M. (2018). The effect of physical exercise after a concussion: a systematic review and meta-analysis. *The American journal of sports medicine*, *46*(3), 743-752.

Langer, L., Levy, C., & Bayley, M. (2020). Increasing incidence of concussion: true epidemic or better recognition? *The Journal of Head Trauma Rehabilitation*, *35*(1), E60-E66.

Langevin, P., Frémont, P., Fait, P., & Roy, J.-S. (2022). Responsiveness of the post-concussion symptom scale to monitor clinical recovery after concussion or mild traumatic brain injury. *Orthopaedic journal of sports medicine*, *10*(10), 23259671221127049.

Lefevre-Dognin, C., Cogné, M., Perdrieau, V., Granger, A., Heslot, C., & Azouvi, P. (2021). Definition and epidemiology of mild traumatic brain injury. *Neurochirurgie*, *67*(3), 218-221.

Lempke, L., Jaffri, A., & Erdman, N. (2019). The effects of early physical activity compared to early physical rest on concussion symptoms. *Journal of sport rehabilitation*, *28*(1), 99-105.

Lovell, M. R., & Collins, M. W. (1998). Neuropsychological assessment of the college football player. *The Journal of Head Trauma Rehabilitation*, *13*(2), 9-26.

Lowry, R., Haarbauer-Krupa, J. K., Breiding, M. J., Thigpen, S., Rasberry, C. N., & Lee, S. M. (2019). Concussion and academic impairment among US high school students. *American journal of preventive medicine*, *57*(6), 733-740.

Luis, C. A., & Mittenberg, W. (2002). Mood and anxiety disorders following pediatric traumatic brain injury: a prospective study. *Journal of clinical and experimental neuropsychology*, *24*(3), 270-279.

MacFarlane, M. P., & Glenn, T. C. (2015). Neurochemical cascade of concussion. *Brain injury*, *29*(2), 139-153.

Martin, A. K., Petersen, A. J., Sesma, H. W., Koolmo, M. B., Ingram, K. M., Slifko, K. B., Nguyen, V. N., Doss, R. C., & Linabery, A. M. (2022). Learning and attention deficit/hyperactivity disorders as risk factors for prolonged concussion recovery in children and adolescents. *Journal of the International Neuropsychological Society*, *28*(2), 109-122.

Matuszak, J. M., McVige, J., McPherson, J., Willer, B., & Leddy, J. (2016). A practical concussion physical examination toolbox: evidence-based physical examination for concussion. *Sports health*, *8*(3), 260-269.

McCrory, P., Meeuwisse, W. H., Aubry, M., Cantu, B., Dvořák, J., Echemendia, R. J., Engebretsen, L., Johnston, K., Kutcher, J. S., & Raftery, M. (2013). the 4th International conference on concussion in sport held in Zurich, November 2012. *Br J Sports Med*, *47*(5), 250-258.

McInnes, K., Friesen, C. L., MacKenzie, D. E., Westwood, D. A., & Boe, S. G. (2017). Mild Traumatic Brain Injury (mTBI) and chronic cognitive impairment: A scoping review. *PloS one*, *12*(4), e0174847.

McKinlay, A., Bishop, A., & McLellan, T. (2011). Public knowledge of 'concussion'and the different terminology used to communicate about mild traumatic brain injury (MTBI). *Brain injury*, *25*(7-8), 761-766.

McNamee, M. J., Partridge, B., & Anderson, L. (2016). Concussion ethics and sports medicine. *Clinics in sports medicine*, *35*(2), 257-267.

McVige, J., Shukri, S., Bargnes, V., & Lillis, M. (2018). Neuroimaging of concussion patients in an outpatient clinic. *Neurology*, *91*(23_Supplement_1), S14-S14.

Ministry of Education. (2025). *Guide to Acquired brain injury and learning*.

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.

Musumeci, G., Ravalli, S., Amorini, A. M., & Lazzarino, G. (2019). Concussion in sports. *Journal of functional morphology and kinesiology*, *4*(2), 37.

Novak, Z., Aglipay, M., Barrowman, N., Yeates, K. O., Beauchamp, M. H., Gravel, J., Freedman, S. B., Gagnon, I., Gioia, G., & Boutis, K. (2016). Association of persistent postconcussion symptoms with pediatric quality of life. *JAMA pediatrics*, *170*(12), e162900-e162900.

Peng, P., & Kievit, R. A. (2020). The development of academic achievement and cognitive abilities: A bidirectional perspective. *Child Development Perspectives*, *14*(1), 15-20.

Pervez, M., Kitagawa, R. S., & Chang, T. R. (2018). Definition of traumatic brain injury, neurosurgery, trauma orthopedics, neuroimaging, psychology, and psychiatry in mild traumatic brain injury. *Neuroimaging Clinics*, *28*(1), 1-13.

Ponsford, J., Nguyen, S., Downing, M., Bosch, M., McKenzie, J. E., Turner, S., Chau, M., Mortimer, D., Gruen, R. L., & Knott, J. (2019). Factors associated with persistent post-concussion symptoms following mild traumatic brain injury in adults. *Journal of rehabilitation medicine*, *51*(1), 32-39.

Romm, K. E., Ambegaonkar, J. P., Caswell, A. M., Parham, C., Cortes, N. E., Kerr, Z., Broshek, D. K., & Caswell, S. V. (2018). Schoolteachers' and administrators' perceptions of concussion management and implementation of return-to-learn guideline. *Journal of School Health*, *88*(11), 813-820.

Rooks, C. R., Thom, N. J., McCully, K. K., & Dishman, R. K. (2010). Effects of incremental exercise on cerebral oxygenation measured by near-infrared spectroscopy: a systematic review. *Progress in neurobiology*, *92*(2), 134-150.

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.

Salari, N., Ghasemi, H., Abdoli, N., Rahmani, A., Shiri, M. H., Hashemian, A. H., Akbari, H., & Mohammadi, M. (2023). The global prevalence of ADHD in children and adolescents: a systematic review and meta-analysis. *Italian journal of pediatrics*, *49*(1), 48.

Schneider, K. J., Leddy, J. J., Guskiewicz, K. M., Seifert, T., McCrea, M., Silverberg, N. D., Feddermann-Demont, N., Iverson, G. L., Hayden, A., & Makdissi, M. (2017). Rest and treatment/rehabilitation following sport-related concussion: a systematic review. *British journal of sports medicine*, *51*(12), 930-934.

Silverberg, N. D., Iverson, G. L., McCrea, M., Apps, J. N., Hammeke, T. A., & Thomas, D. G. (2016). Activity-related symptom exacerbations after pediatric concussion. *JAMA pediatrics*, *170*(10), 946-953.

Starkey, N. J., Jones, K., Case, R., Theadom, A., Barker-Collo, S., & Feigin, V. (2018). Post-concussive symptoms after a mild traumatic brain injury during childhood and adolescence. *Brain injury*, *32*(5), 617-626.

Sussman, E. S., Pendharkar, A. V., Ho, A. L., & Ghajar, J. (2018). Mild traumatic brain injury and concussion: terminology and classification. *Handbook of clinical neurology*, *158*, 21-24.

Teasdale, G., & Jennett, B. (1974). Assessment of coma and impaired consciousness: a practical scale. *The Lancet*, *304*(7872), 81-84.

Theadom, A., Mahon, S., Hume, P., Starkey, N., Barker-Collo, S., Jones, K., Majdan, M., & Feigin, V. L. (2020). Incidence of sports-related traumatic brain injury of all severities: a systematic review. *Neuroepidemiology*, *54*(2), 192-199.

Varni, J. W. (1998). *Pediatric Quality of Life Inventory (PedsQL)*.

Varni, J. W., Burwinkle, T. M., Seid, M., & Skarr, D. (2003). The PedsQL™* 4.0 as a pediatric population health measure: feasibility, reliability, and validity. *Ambulatory pediatrics*, *3*(6), 329-341.

Vaughan, C. G., Ledoux, A.-A., Sady, M. D., Tang, K., Yeates, K. O., Sangha, G., Osmond, M. H., Freedman, S. B., Gravel, J., & Gagnon, I. (2023). Association between early return to school following acute concussion and symptom burden at 2 weeks postinjury. *JAMA network open*, *6*(1), e2251839-e2251839.

Veliz, P., McCabe, S. E., Eckner, J. T., & Schulenberg, J. E. (2021). Trends in the prevalence of concussion reported by US adolescents, 2016-2020. *JAMA*, *325*(17), 1789-1791.

Vos, L., Whiteneck, G. G., Ngan, E., Leon Novelo, L., Harik, L. M., & Sherer, M. (2019). Comparison of the neurobehavioral symptom inventory and the Rivermead Postconcussion Symptoms Questionnaire. *Brain injury*, *33*(9), 1165-1172.

Waltzman, D., & Daugherty, J. (2018). Concussion knowledge and experience among a sample of American adults. *Journal of Concussion*, *2*, 2059700218769218.

Wan, A. N., & Nasr, A. S. (2021). Return to learn: An ethnographic study of adolescent young adults returning to school post-concussion. *Journal of clinical nursing*, *30*(5-6), 793-802.

Wells, E. M., Goodkin, H. P., & Griesbach, G. S. (2016). Challenges in determining the role of rest and exercise in the management of mild traumatic brain injury. *Journal of child neurology*, *31*(1), 86-92.

Wilmoth, K., Tan, A., Hague, C., Tarkenton, T., Silver, C. H., Didehbani, N., Rossetti, H. C., Batjer, H., Bell, K. R., & Cullum, C. M. (2019). Current state of the literature on psychological and social sequelae of sports-related concussion in school-aged children and adolescents. *Journal of experimental neuroscience*, *13*, 1179069519830421.

Yengo-Kahn, A. M., Reynolds, R. A., & Bonfield, C. M. (2021). Mild traumatic brain injury in children. *Pediatric Clinics*, *68*(4), 857-874.

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), 259-265.

Zhang, C., Tang, K., Zemek, R., Beauchamp, M. H., Craig, W., Doan, Q., & Yeates, K. O. (2023). 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.