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RESEARCH ARTICLE

Mood and anxiety symptoms following pediatric mild traumatic brain injury: a scoping review

Seemab Sabir, B.A.[1] and Rebecca Malhi, PhD[2]

Abstract

Background: Thousands of children sustain mild traumatic brain injuries (mTBI) worldwide each year. Multiple physical and somatic symptoms can occur following pediatric mTBI, including new-onset mood symptoms, headaches, and pain. **Objective:** This scoping review examined the existing literature pertaining to mood and anxiety symptoms following pediatric mTBI, in order to summarize the current evidence and identify areas for future research. **Methods:** The Pubmed, EMBase, and APA PsycINFO databases were searched to identify articles that examined mood and anxiety symptoms in children and adolescents following mTBI. **Results:** A total of 20 published articles were included in the review. The existing research suggests that mood and anxiety symptoms are more common in children and adolescents with mTBI, when compared to orthopedically injured or healthy controls. Several factors may contribute to the development of these symptoms: injury characteristics, older age at injury, female sex, and psychosocial variables including lower socioeconomic status and family history of psychiatric disorders. **Conclusion:** The findings of this review highlight the need for additional research on the relationship between pediatric mTBI and subsequent mood and anxiety symptoms. We particularly recommend long-term prospective cohort studies which include appropriate control groups as well as a neuroimaging component to distinguish complicated from uncomplicated mTBI.

Key Words: *concussion, pediatric, mood disorder, anxiety, review*

Résumé

Contexte: Des milliers d'enfants subissent des traumatismes crâniens légers (TCI) dans le monde entier chaque année. De multiples symptômes physiques et somatiques peuvent se produire par suite d'un TCI pédiatrique, y compris des symptômes de l'humeur nouvellement apparus, des maux de tête et des douleurs. **Objectif:** Cet examen de la portée a examiné la littérature existante concernant les symptômes de l'humeur et d'anxiété suivant un TCI pédiatrique, afin de résumer les données probantes actuelles et d'identifier les domaines de la future recherche. **Méthodes:** Les bases de données Pubmed, EMBase, et APA PsycINFO ont été recherchées pour identifier les articles qui examinaient les symptômes de l'humeur et d'anxiété chez les enfants et les adolescents après le TCI. **Résultats:** Un total de 20 articles publiés a été inclus dans la revue. La recherche existante suggère que les symptômes de l'humeur et d'anxiété sont plus communs chez les enfants et les adolescents qui ont un TCI, lorsque comparés avec les blessés orthopédiquement ou les témoins en santé. Plusieurs facteurs peuvent contribuer au développement de ces symptômes: caractéristiques de la blessure, plus âgé lors de la blessure, sexe féminin, et variables psychosociales dont un statut socio-économique plus faible, et antécédents familiaux de troubles psychiatriques. **Conclusion:** Le résultats de cette revue mettent en valeur le besoin de recherche additionnelle sur la relation entre le TCI pédiatrique et les symptômes de l'humeur et d'anxiété subséquents. Nous recommandons particulièrement les études de cohorte à long terme qui incluent des groupes témoins appropriés ainsi qu'une composante de neuroimagerie pour distinguer la forme compliquée de la forme non compliquée du TCI.

Mots clés: *commotion cérébrale, pédiatrique, trouble de l'humeur, anxiété, revue*

[1]Department of Psychology, University of Calgary, Calgary, Alberta
[2]Department of Community Health Sciences, Cumming School of Medicine, University of Calgary, Calgary, Alberta

Corresponding E-mail: ssabi041@mtroyal.ca

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Introduction

Traumatic brain injury occurs in 69 million people worldwide per year, including over 3 million children (1). Of these cases, an estimated 80% were classified as mild traumatic brain injury (mTBI), also known as *concussion* (2). An estimated 692 out of 100,000 children present to emergency departments annually with pediatric mTBI in the United States alone (3). However, a study by Powell et al (4) found that over 56% of mTBI cases go undiagnosed. Patients with untreated mTBIs could potentially have lengthened recovery times due to a lack of post-discharge management education (4). As well, compared to healthy controls, patients with a history of mTBI have an increased risk for the development of long-term medical and behavioral comorbidities (5).

The definition of mTBI is often disputed, with different organizations reporting different qualifying criteria. Some of the key issues in contention include the use of the Glasgow Coma Scale, the duration of altered consciousness, and the presence of neurological symptoms following injury. The lack of consensus on mTBI diagnostic criteria fosters a situation in which many cases of mTBI are left undiagnosed, even when patients report symptoms consistent with an mTBI diagnosis. This is illustrated by the results from a 2019 study of patients presenting to a trauma and emergency care centre in the United States. Koval et al (6) found that an evaluation for mTBI was conducted in less than 50% of patients with a head injury, and only 41% of patients who were diagnosed with mTBI received post-discharge mTBI education.

Research shows that most adults will recover from mTBI within 12 months of injury (7). However, a significant minority will still experience persistent post-concussive symptoms (also known as post-concussion syndrome; PCS), such as fatigue and headaches (7). There is also an increased risk for psychiatric disorders (8).

Pediatric mTBI can cause physical, affective, and cognitive symptoms (9-11). Resolution of symptoms to premorbid levels occurs one month following mTBI in most children, but 13-16% of symptoms can persist several months post-injury (9). Changes in mood, including irritability and other symptoms of anxiety and depression, as well as new-onset mood disorders (also referred to as novel psychiatric disorders; NPD), can also occur after TBI in children (12-14). These symptoms can negatively impact patients' quality of life and recovery (15)

Mood disorders including depression are common in children and adolescents in the general population, with 17% of adolescents in the US reporting a major depressive episode in 2020 (16). Anxiety and depressive symptoms are often comorbid in pediatric populations. Between 25-50% of children and adolescents with depression also have comorbid anxiety (17). If left undiagnosed or untreated, anxiety and pediatric depression can lead to many negative consequences that can persist into adulthood including disability, a loss of productivity, a high risk for suicide (18), criminal behavior, and dysfunctional interpersonal relationships (19).

Although it is a significant medical issue, few studies have been conducted in children on the effects of pediatric mTBI. One exception is a literature review by Laliberte et al (20) which examined the relationship between pediatric TBI and depression. However, this review only considered depression as an outcome and was not restricted to mTBI. The aim of this study is to examine the occurrence of mood and anxiety disorders following mTBI in children and identify any potential gaps in the research using a scoping review.

Methods

This review followed Arksey and O'Malley's methodological framework for scoping reviews (21). The steps for the framework are: (a) identifying the research question, (b) identifying relevant studies, (c) study selection, (d) charting the data, and (e) collating, summarizing, and reporting results.

The databases Pubmed, EMBase, and APA PsycINFO were searched in April 2022 for relevant studies published in peer-reviewed academic journals since 2002. The timeframe of twenty years was arbitrary but was selected with the assumption that older high-quality studies would be cited and their findings incorporated into newer published research. We reasoned that more recent studies would include updated information that supersedes older findings. The database search (see Appendix A for search terms) identified 3107 papers: 1105 from APA PsycInfo, 1267 from EMBase, and 735 from Pubmed. One additional article was found after a hand-search of citing articles.

Results from the database search were imported into a Microsoft Excel spreadsheet. After duplicate records were removed, article titles and abstracts were reviewed for relevance. This scan resulted in 1,940 articles being excluded. The remaining 143 articles were selected for full-text review and assessed for eligibility. Abstracts of these articles were reviewed using the following inclusion criteria: (a) Study participants must be below the age of 18 at the time of injury and (b) the study must assess mood disorders or symptoms as an outcome following mTBI. For the purpose of this review, concussion and mTBI were used synonymously. Review papers, articles without abstracts, and non-English language studies were excluded. Of the 143 articles

reviewed, 123 articles did not meet inclusion criteria and were excluded from further analysis. Twenty studies, therefore, met the inclusion criteria. A diagram of the search process is shown in Figure 1.

Both authors independently appraised each of the 20 included articles for study quality using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies (22). Items assessed included selection bias, study design, confounders, blinding, reliability/validity of data collection tools, and study withdrawals. Based on these item assessments, each study was given an overall global quality assessment rating (Weak, Moderate, and Strong). Each article was also reviewed for quality of evidence, using items that are pertinent to the topic of pediatric mTBI: prospective versus retrospective study design, chart review versus in-person assessments, consecutively treated for mTBI versus referred/clinic sample, symptom checklists versus standardized interviews, and the presence of a control group.

Results

Study Characteristics

An overview of the study designs, populations, and relevant findings from each of the 20 included articles can be found in Table 1. The final set of papers had a variety of study designs, including retrospective, cross-sectional, and prospective cohort studies, as well as randomized controlled trials and case series. Of the 20 included articles, there were 2 retrospective chart reviews, 1 cross-sectional study, 14 prospective cohort studies, 1 retrospective cohort study, 1 randomized controlled trial, and 1 retrospective survey. Seven articles included a non-mTBI control group while 10 articles did not. A variety of assessment tools were used including questionnaires, symptom checklists, and standardized interviews. In 9 studies, participants were treated immediately after injury (consecutively treated) for mTBI, 4 used samples of patients referred to clinics, 2 used both

Figure 1. Literature Review Process

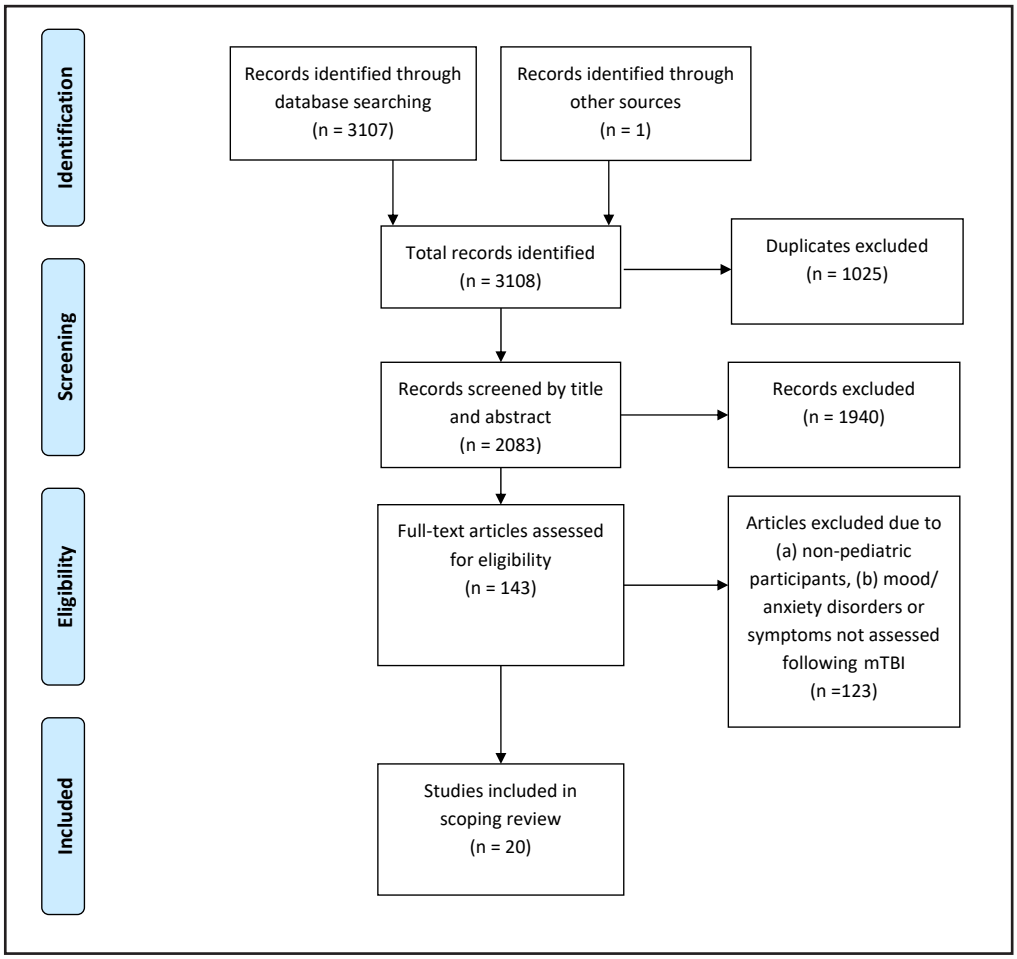

Table 1. Overview of mild traumatic brain injury studies included in scoping review

Author(s), Year of publication	Study design	Study population	Measured variables	Relevant Findings	Author EPHPP Quality Rating
Chrisman and Richardson, 2014 (13)	Retrospective cohort	Adolescents aged 12-17 (N = 36,060)	Age, sex, parent mental health, history of concussion, diagnosis of depression	2.7% of participants had a history of concussion and 3.4% had a current diagnosis of depression; 7.8% of currently depressed subjects had a history of concussion. History of concussion was associated with a 3.3-fold greater risk for depression.	Moderate
Luis and Mittenberg, 2002 (14)	Prospective cohort	Children (N = 96) with mTBI (n = 45), moderate/severe TBI (n = 19), and orthopedic controls	DISC-IV Modules A and C, DSM-IV criteria, SRRQ, age, gender, race, parental level of education and parental occupation	The TBI group reported significantly more psychiatric disorders at the 6-month follow up than the controls (46% versus 14%). 38.1% of the mTBI group developed a new-onset disorder (NOD).	Moderate
Tham et al., 2015 (27)	Prospective cohort	Adolescents (N = 100) with mTBI (n = 50), and healthy controls (n = 50)	Age, sex, race, ethnicity, household income, pain intensity (NRS), CES-D, ASWS, PSA, Actigraphy sleep assessment	36% of the mTBI group met criteria for depressive illness compared to 12% of the healthy control group. Greater depressive symptoms were associated with poorer sleep quality in both groups.	Moderate
Ho et al., 2020 (28)	Cross-sectional	Children and adolescents (N = 30) with a diagnosis of concussion and symptomatic at time of recruitment	PCSI, CDI 2, ImPACT	Heightened emotionality, irritability, and nervousness were commonly reported by subjects with post-concussive depression. Sadness and fatigue were reported by patients with and without post-concussive depression.	Strong
Connolly and McCormick, 2019 (29)	Longitudinal cohort	Children and adolescents aged 10-18 (N = 1827)	History of mTBI, CBCL/4-18, parent-child conflict, victimization, Vocabulary subtest of the Wechsler Intelligence Scale for Children-Revised, race, sex	mTBI was positively associated with an increase in anxiety/depression, aggressive behaviour, and delinquency.	Moderate
Macartney et al., 2021 (30)	Retrospective chart review	Concussion clinic patients aged 6-18 (N = 155)	PCSI, KAD-6, GAD-7	Low overall mean depression and anxiety scores were reported. There is a statistically significant association between PCSI scores and KAD-6 scores as well as GAD-7 scores in males and females.	Moderate
O'Connor et al., 2012 (31)	Prospective cohort	(n = 35) moderate/severe TBI (n = 31), and arm-injured controls (n = 39)	Preinjury functioning, PHQ-9, DSM-IV criteria, PedsQL, FAD General Functioning Scale	No significant differences were found between TBI groups and the arm-injured groups for depressive symptoms.	Moderate

continued

Table 1. Continued

Author(s), Year of publication	Study design	Study population	Measured variables	Relevant Findings	Author EPHPP Quality Rating
Hammer et al., 2020 (32)	Prospective cohort	High school athletes (N = 2160)	Demographics, PHQ-9, SCAT5	5.8% of participants sustained an SRC over the course of two years. PHQ-9 scores returned to normal by return to sport, and there was no significant difference in PHQ-9 scores between	Moderate
Max et al., 2021 (33)	Prospective Cohort	Children and adolescents who sustained an mTBI (N = 220) or OI (N = 110) and were seen at the emergency department	ISS, AIS, K-SADS-PL, NPRS, TRF, DSM-IV, Vineland Adaptive Behavior Scales, WASI, CRS, WRAT-4, McSIFF, FAD, Family History Research Diagnostic Criteria	NPD occurred in a higher rate of children with mTBI than with OI (mean ratio [MR] 3.647, 95% confidence interval [CI95] (1.264, 15.405), p = 0.014).	Strong
Chrisman et al., 2021 (34)	Randomized controlled trial	Children diagnosed with a sports-related or recreation-related concussion (N = 200)	Demographics, injury characteristics, history of mental health or chronic pain, ASWS-28, UCLA Trauma History Profile, National Comorbidity Trauma History Screen, PHQ-9, GAD-7	40% of the sample reported significant depressive symptoms, 25% significant anxiety symptoms, 14% thoughts of death/self-harm, and 8% thoughts of suicide.	Weak
Max et al., 2013 (35)	Prospective cohort	Children who sustained mTBI (N = 79)	K-SADS-PL, DSM-IV criteria, NPRS, lesions on MRI, GCS score, Survey Diagnostic Instrument, AIS, ISS, Family History Research Diagnostic Criteria, FAD General Functioning Scale, Four-Factor Index, psychosocial adversity, Vineland Adaptive Behavior Scale, Woodcock-Johnson Revised Letter-Word Identification, WISC-III, Rapid Automatized Naming task, CVLT–C, CELF-3	23% of subjects developed NPD by the 12-month assessment, including generalized anxiety disorder (n = 3), major depressive disorder (n = 2), and separation anxiety disorder (n =1)	Moderate
Gillie et al., 2022 (36)	Observational cohort	Children who presented to a concussion specialty clinic (N = 129)	VOMS, ImPACT, PCSS, SCARED-C, GAD-7	21.7% of subjects displayed levels of anxiety consistent with a diagnosis of anxiety disorder. 13.2% met or exceeded clinical cutoffs for post-injury anxiety.	Strong
Max et al., 2013 (37)	Prospective cohort	Children who sustained mTBI (N = 87)	DSM-IV criteria, K-SADS-PL, NPRS, GCS score, AIS, ISS, lesions on MRI, Family History Research Diagnostic Criteria, FAD general functioning scale, Four-Factor Index, psychosocial adversity, Vineland Adaptive Behavior Scale, Woodcock-Johnson Revised Calculation and Letter–Word Identification, WISC-III, WASI, CELF-3, Stroop Color-Word Inference Task, SSRT	36% of subjects developed NPD by the 12-month assessment, including major depressive disorder (n = 3), generalized anxiety disorder (n = 2), and separation anxiety disorder (n = 2)	Moderate

continued

Table 1. Continued

Author(s), Year of publication	Study design	Study population	Measured variables	Relevant Findings	Author EPHPP Quality Rating
Max et al., 2015 (38)	Prospective cohort	Children who sustained mTBI (N = 87)	DSM-IV criteria, K-SADS-PL, NPRS, GCS score, AIS, ISS, lesions on MRI, Family History Research Diagnostic Criteria, FAD general functioning scale, Four-Factor Index, psychosocial adversity, Vineland Adaptive Behavior Scale, Woodcock-Johnson Revised Calculation and Letter–Word Identification, WISC-III, WASI, CELF-3, Stroop Color-Word Inference Task, SSRT	19% of subjects who returned for the 24-month assessment developed NPD, including depressive disorders (n = 3) and anxiety disorders (n = 3).	Moderate
Ellis et al., 2015 (39)	Retrospective chart review	Pediatric patients referred to a concussion program between September 2013 and October 2014 (N = 174)	Demographic information, sport played at time of injury, medical history, past concussion history, family history, PCSS	49.4% of participants reported at least one emotional symptom. 11.5% of participants met the criteria for a postinjury psychiatric outcome, including NPD (n = 14), isolated suicidal ideation (n = 2), and worsening symptoms of a preinjury psychiatric disorder (n = 4).	Weak
Massagli et al., 2004 (40)	Prospective cohort	Children (N = 1960) with mTBI (n = 490) and unexposed controls (N = 1470)	ICD-9-CM codes for psychiatric diagnosis, filling of prescription for psychiatric medication, or utilization of psychiatric services	Psychiatric illness was found in a greater percentage of children with mTBI compared to unexposed controls (30% versus 20%) in the three years post-injury. An estimated 3% of children with mTBI are predicted to develop affective disorders including depression and anxiety disorders.	Moderate
Brooks et al., 2019 (41)	Prospective cohort	Children and adolescents who sustained a concussion within the past 48 hours and presented to the emergency department (N = 311)	Demographics, past medical, developmental, and psychiatric histories, injury characteristics, PCSI, SAC, M-BESS, SCAT, CBCL, SDQ	Psychological distress was experienced by 19.4% of participants at the 4-week follow-up and 24.1% at the 12-week follow-up.	Weak
McKinlay et al., 2009 (42)	Longitudinal birth cohort	Children (N = 1265) who were admitted to a hospital for mTBI (n = 19), who were sent home	Premorbid and post-injury functioning, DSM-III-R criteria, Revised Behavior	Children who were hospitalized for mTBI were significantly more likely to display symptoms of mood disorder, substance abuse, and CD/ODD but not anxiety disorder.	Strong

continued

Table 1. Continued

Author(s), Year of publication	Study design	Study population	Measured variables	Relevant Findings	Author EPHPP Quality Rating
Chendrasekhar et al., 2020 (43)	Retrospective survey	Children and adolescents (N = 100) who sustained mTBI	ISS, AIS-H, RTS, GCS score, vital signs, pre-existing conditions, post-injury symptoms	33% of participants reported residual effects following injury; 21% of participants who reported sequelae had anxiety/ depression issues.	Weak
Starkey et al., 2018 (44)	Prospective cohort	Children and adolescents (N = 184) with mTBI (n = 117) and TBI free controls (n = 67)	Demographics, injury characteristics, pre-injury health, RPQ, BASC-2, Hospital Anxiety and Depression Scale	mTBI group reported more PCSs and behavioural problems than the control group. The proportion of children with clinically significant internalizing problems increased over time in the mTBI group.	Weak

Abbreviations: AIS, Abbreviated Injury Scale; ASWS, Adolescent Sleep Wake Scale; CBCL/4-18, Child Behavior Checklist for Ages 4-18; CD, conduct disorder; CDI 2, Children's Depression Inventory; CELF-3, Clinical Evaluation of Language Fundamentals, 3rd Edition; CES-D, Center for Epidemiological Studies Depression Scale; CRS, Clinical Rating Scale; CVLT-C, California Verbal Learning Test-Children's Version; DISC-V, Diagnostic Interview Schedule for Children - 4th edition; DSM-III-R, Diagnostic & Statistical Manual of Mental Disorders–3rd Edition Revised; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, 4th Edition; FAD, Family Assessment Device; GAD-7, Generalized Anxiety Disorder 7-item; GCS, Glasgow Coma Scale; ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; ImPACT, Immediate Post-Concussion Assessment and Cognitive Test; ISS, Injury Severity Score; KAD-6, 6-item Kutcher Adolescent Depression Scale; K-SADS-PL, Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version; M-BESS, Modified Balance Error Scoring System; McSIFF McMaster Structured Interview of Family Functioning; MRI, magnetic resonance imaging; NOD, new-onset disorder; NPD, new-onset (novel) psychiatric disorder; NPRS, Neuropsychiatric Rating Schedule; NRS, Numeric Rating Scale; ODD, oppositional defiant disorder; PCSI, Post-Concussion Symptom Inventory; PCSS, Post-Concussion Symptom Scale; PSA, Pre-Sleep Arousal; RPQ, Rivermead Post-Concussion Symptoms Questionnaire; RTS, Revised Trauma Score; SAC, Standardized Assessment of Concussion; SCARED-C, Screening for Child Anxiety Related Disorders—Child Report; SCAT, Child-Sport Concussion Assessment Tool; SDQ, Strengths and Difficulties Questionnaire; SRC, sports-related concussion; SRRQ, Social Readjustment Rating Questionnaire; Stop Signal Reaction Time Task; TRF, Teacher's Report Form; VOMS, Vestibular Ocular-Motor Screening; WASI, Wechsler Abbreviated Scale of Intelligence; WISC-III, Wechsler Intelligence Scale for Children–III; WRAT-4, Wide Range Achievement Test-Fourth Edition

consecutively treated and clinically referred patient samples, and 5 were unknown or not applicable.

The majority of the included studies included participants from North America including 11 studies with participants from the United States, 4 from Canada, and 3 from both the United States and Canada. Another 2 studies included participants from New Zealand.

Using the EPHPP Quality Assessment Tool, 4 included articles were rated as "Strong", 11 as "Moderate", and 5 as "Weak". We had an initial inter-rater reliability of 85% agreement. Disagreements were discussed by the authors until consensus was reached.

Definition of mTBI

The World Health Organization (WHO) defines mTBI as a Glasgow Coma Scale (GCS) score of 13 to 15 out of 15 that is accompanied by at least one of the following symptoms: loss of consciousness (LOC) less than 30 minutes, post-traumatic amnesia (PTA) less than 24 hours, impaired mental state at the time of injury, or transient neurological deficit (23). The Zurich consensus statement defines concussion as a brain injury with "*a complex pathophysiological process affecting the brain, induced by biomechanical forces*" (24, pp1). Several studies also use International Classification of Diseases (ICD)-9 codes to define mTBI. Relevant ICD-9 codes include: skull fracture (800.0, 800.5, 801.0, 801.5, 803.0, 803.5, 804.0, or 804.5), concussion (850.0, 850.1, 850.5, or 850.9), intracranial injury of other and unspecified nature (854.0), or head injury, unspecified (959.01) (25).

The included studies used several different criteria to determine exposure to mTBI. Two studies used the Zurich Consensus Statement on Concussion in Sport (24). One study used diagnostic categories from the Centers for Disease Control and Prevention (CDC), which encompass multiple ICD-9 codes. Six papers used a combination of diagnostic criteria, including GCS scores, length of time where there was a loss of consciousness, and neuroimaging. Three

studies did not specify diagnostic criteria as participants were recruited from either concussion specialty clinics or hospitals following injury. The remainder of the articles (n = 8) used an array of measures, including chart reviews, parental reports, self-reports, the WHO Task Force definition of mTBI, the Abbreviated Injury Scale - Head, and Injury Severity Scores. Despite the use of different criteria, there was general agreement that mTBI is a closed-head injury resulting from blunt-force trauma. Some articles discussed mTBI cases with abnormalities on neuroimaging, known as complicated mTBI (26).

Depression and Depressive Symptoms

The studies in the scoping review reported rates of depression following pediatric mTBI ranging from 0% to 40%, depending on the assessment interval and instrument. Tham et al (27) reported that in the first 12 months following injury, 36% of children with mTBI met the Center for Epidemiologic Studies Depression Scale (CES-D) measure for depressive symptoms, compared to 12% of healthy controls. Chrisman and Richardson (13) found that a history of concussion was associated with a 3.3-fold greater risk for depression in patients (95% CI: 2.0–5.5), compared to patients with no history of concussion. Ho et al (28) reported that 83.3% of adolescents experienced at least one depressive symptom on the Children's Depression Inventory 2 (CDI 2) after concussion, with sadness and irritability being the most commonly reported symptoms. Connolly and McCormick (29) found that when compared to individuals without mTBI, participants with mTBI are significantly more likely to report symptoms of depression (95% CI: 0.10-0.41) in the 2.5 years following injury, even after controlling for prior histories of depression.

The remaining studies, however, did not find an association between pediatric mTBI and depression. For example, Macartney et al (30) reported a mean 6-item Kutcher Adolescent Depression Scale depression score of 4.7 (range 0-18), indicating low levels of depression post-injury. Similarly, O'Connor et al (31) found no significant differences in rates of depressive symptoms between head injury and arm injury groups in the first 24 months post-injury. According to Hammer et al (32), mood symptoms only slightly worsened after injury but returned to baseline within a few months. Max et al (33) reported no difference in rates of new-onset depressive disorders between children with mTBI and children with orthopedic injury (OI), with neither group reporting depressive symptoms at 3 months post-injury.

Anxiety

Clinically significant anxiety and associated symptoms following pediatric mTBI were noted by several studies included in the review. Christman et al (34) found that 25% of youth with concussions met the guidelines for clinically significant anxiety. A variety of anxiety disorders as defined by DSM-IV criteria, including generalized anxiety disorder and separation anxiety disorder, were reported by Max et al (35) in 6% of subjects aged 5-14 years old in the first 12 months post-injury. Using a combination of DSM-IV diagnostic criteria and the Screen for Child Anxiety Related Disorders, Gillie and colleagues (36) found that over 13% of concussed youths met or exceeded clinical cutoffs for anxiety, noting that clinically significant anxiety appeared to be associated with non-sports related concussion injuries as well as pre-injury panic symptoms. Connolly and McCormick (29) also found elevated incidences of anxiety after mTBI in participants aged 10-18 years old. New-onset anxiety disorders were reported by Max et al (33) as 2.1% and 1.1% in the mTBI and OI groups at 3 months post-injury, respectively.

Of the articles reviewed, only one article did not find a significant association between mTBI and post-injury anxiety symptoms. Participants in the Macartney et al (30) study only had a mean General Anxiety Disorder-7 score of 7.4 (range 0-24), indicating low levels of anxiety overall.

New-onset mood disorders and psychiatric outcomes

Several studies analyzed general rates of new-onset mood disorders or new-onset psychiatric disorders that occurred following mTBI. Luis and Mittenberg (14) found that over 38% of pediatric mTBI subjects developed a new-onset mood disorder, compared to 14% of controls. These disorders included social phobia, separation anxiety, panic attacks, agoraphobia, obsessive-compulsive disorder, post-traumatic stress disorder, and major depressive disorder. Across several prospective cohort studies, Max and colleagues (33, 35, 37, 38) found that between 19% and 36% of children and adolescents with mTBI presented with new-onset (novel) psychiatric disorders (NPD) in the first two years following injury. Ellis et al (39) noted that emotional symptoms, including sadness, irritability, and/or nervousness, were found in 49.4% of concussion patients, as well as NPD in 8% of patients.

Massagli et al (40) also found significantly higher rates of psychiatric illness in mTBI patients compared to OI patients, estimating 30% in the mTBI group and 20% in the OI group ($p = 0.0001$). In that study, psychiatric illness was operationalized as psychiatric diagnosis, the filling of a prescription for a psychiatric medication, or use of psychiatric

services post-injury. A study by Brooks et al (41) reported that one in five children presented with elevated levels of psychological distress within the first three months after injury. McKinlay et al (42) found that up to 58% of adolescents who sustained mTBI had behaviors consistent with one or more psychiatric disorders, compared to 43% of non-mTBI controls.

Chrisman et al (34) noted that thoughts of death or self-harm as well as thoughts of suicide were reported in 14% and 8% of subjects with persistent post-concussive symptoms after mTBI, respectively. Anxiety and depression issues were described by Chendrasekhar et al (43) as long-term sequelae in 20% of mTBI patients. Similarly, Starkey et al (44) reported higher internalizing symptoms including anxiety, depression, and other somatization issues over time in the mTBI group versus uninjured controls, noting up to 14.1% and 6.2% in the first 12 months of the study, respectively.

Pre-injury Psychiatric History

The presence of a pre-injury psychiatric diagnosis was associated with an increased risk of developing a new-onset mood disorder (33). Chrisman et al (34) reported a higher risk for suicidality and self-harm in children with a history of depression and anxiety. Preinjury anxiety was also associated with post-injury psychological distress, anxiety, and lingering post-concussive problems. Max et al (33) found that the presence of a pre-injury psychiatric disorder was significantly associated with higher NPD counts following injury.

Interestingly, Massagli et al (40) found higher occurrences of novel diagnoses in uninjured children with psychiatric histories when compared to children with mTBI and psychiatric histories. Research is needed to further explicate this finding and determine if pre-injury psychiatric histories significantly increase the risk of novel diagnoses post-injury.

Discussion

This scoping review examined the current literature on the relationship between pediatric mild traumatic brain injury and mood disorders and their symptoms. There is some evidence to suggest that mood symptoms are commonly seen following mTBI in children. However, the distinction between increased mood symptomology versus a formal diagnosis of a mood disorder is not clear. Five studies used DSM-IV diagnostic criteria, and one study used DSM-III-R criteria. The remaining studies used a variety of methods including structured interviews, self-reports, parental reports, and symptom rating questionnaires. Although these assessment tools aid in analyzing the prevalence of mood and anxiety symptoms in a pediatric population, they may not always provide benchmarks for clinically significant levels of reported symptoms. The use of self-reports and questionnaires raises the question of whether all the mood symptoms that a patient may be experiencing are accounted for when making a clinical diagnosis.

Additionally, few studies assessed long-term mood-related outcomes. The majority of studies conducted follow-up between 3 and 6 months after injury, and only one paper analyzed the incidence of psychiatric illness 3 years after mTBI in children. Though it is generally accepted that many post-injury outcomes resolve within a few weeks (9), some evidence suggests that psychiatric outcomes may carry on well after 6 months post-injury (35, 37, 38, 40) In addition to increased rates of psychiatric outcomes, pediatric mTBI patients may be at risk for long-term behavioural outcomes, including being more likely to be arrested and involved with violent offences (42). There is a need for prospective cohort studies in order to assess the longitudinal outcomes of mTBI in children.

Another issue highlighted by this review was the lack of consistency between control groups. Many studies included non-injured subjects as controls, whereas others included an OI control group. The inclusion of an uninjured control group rather than an OI group does not take into account outcomes that can be attributed to acute injury to the body, regardless of anatomical location.

Although this review focused on mood disorders and symptoms, several non-mood related outcomes were also observed across the included studies. For example, reduced adaptive functioning (35), decrements in expressive functioning and expressive language (37), memory loss (43), learning disability (43), and sleep disturbance (27, 43) were all found to be associated with mTBI. However, such symptoms and their associated mental and physical outcomes are beyond the scope of this review and warrant further investigation.

Other Confounders

There were several non-injury factors that appeared to be associated with mood disturbances following mTBI. These potential confounders include family psychiatric history, socioeconomic status, age, sex, and parent mental health.

There is little concurrence on the true extent of the confounding effect of these variables, as findings from multiple studies contradict one another. One study noted that older adolescence is associated with a 1.5-fold greater risk for depression compared to younger adolescence (13), while others found that age is not associated with the occurrence of new-onset psychiatric disorders after injury (33, 35, 37)

Female sex was observed in several instances to be associated with psychiatric outcomes (30, 38, 39) such as higher rates of anxiety and depression. There also appeared to be a correlation between the incidence of NPDs and psychosocial factors. These factors included family functioning (33, 35), lower SES (13), family psychiatric history (33, 39), vestibular dysfunction (33, 36), parent mental health (13), and neurocognitive deficits (35), but they were not analyzed in depth. Due to this, it is undetermined whether the increase in psychiatric outcomes can be attributed to any psychosocial variables, or if the outcomes resulted solely due to the injury and not influenced by any other variable.

Complicated mTBI was examined in several studies. Two studies by Max et al (37, 38) found that frontal white matter lesions were associated with NPD. Contrarily, Max et al (35) also reported in a 2013 study that the location of lesions was not associated with NPD. It is imperative that future studies include a complicated mTBI group and assess lesion location as a potential confounder for the development of NPD post-injury.

Limitations of this review

As this article is a scoping review, no meta-analysis was conducted. The exclusion of non-English articles as well as the exclusion of articles published before 2002 may have resulted in selection bias.

Another limitation of this review concerns complicated mTBI. Of the 20 selected articles, 11 did not include neuroimaging, which is the method for distinguishing between complicated and uncomplicated mTBI. Due to this, it cannot be determined whether instances of new-onset mood disorders and symptoms following concussion can be attributed solely to exposure to mTBI or if the results are confounded by the presence of intracranial lesions.

Only five of the included articles were rated as "strong". Several studies featured weaker study designs such as retrospective chart reviews or a lack of appropriate control groups. However, the articles do represent the state of the current literature and highlight the need for high-quality medical research in this subject area.

Recommendations

Additional research is needed on the relationship between pediatric mTBI and mood disorders. These studies should be long-term (>24 months post-injury) prospective cohort studies in nature and include an orthopedic injury control group. Generally, mTBI and complicated mTBI are assessed as separate categories, but the inclusion of a complicated mTBI group in future studies may provide insight on subsequent symptoms that may be correlated to lesion location. DSM-IV or DSM-V diagnostic criteria should be utilized, as well as in-depth analysis on psychosocial and neurocognitive risk factors. It is crucial to control for potential confounders and the presence of pre-injury psychiatric disorders and symptoms as a risk factor for new-onset symptomology. It is also imperative to conduct further research on non-mood related and somatic PCS including sleep disturbances, pain, memory loss, and vestibular dysfunction.

Within the scope of mTBI, there is evidence to suggest that NPD is associated with more serious cases (i.e., mTBI cases requiring inpatient hospitalization) and the type of injury (sports-related concussion or not). Current literature regarding sports-related concussion (SRC) and its connection to mood outcomes is inconclusive, and very few studies have focused on inpatient mTBI. Future studies on the relationship between new-onset mood disorders and inpatient status following injury as well as studies which consider injury type should be conducted.

Conclusion

Sequelae of pediatric mTBI can include the development of new-onset mood and anxiety disorders or symptomology. Our recommendations for future research may aid in the detection of mood and anxiety outcomes following pediatric mTBI, ultimately resulting in early management and fewer long-term symptoms.

Conflicts of Interest

The authors have no financial relationships or other ties to disclose.

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Appendix A: Pediatric mTBI Scoping Review – Database Searches			
Terms	EMBASE	APA PsychInfo	PubMed
	Keywords & Phrases	Keywords & Phrases	(Title/abstract search)
Child/children Pediatric/paediatric adolescent preschool youth	S1: (child* or pediatri* or paediatri* or adolescen* or preschool* or pre-school* or youth*).ab,kf,ti.	S1: (child* or pediatri* or paediatri* or adolescen* or preschool* or pre-school* or youth*).mp.	S1: (child* or pediatri* or paediatri* or adolescen* or preschool* or pre-school* or youth*)
Concussion / post-concussive mTBI mild/ traumatic brain injury	S2: (concuss* or mtbi* or «traumatic brain injur*» or «mild traumatic brain injur*» or post-concuss*).ab,kf,ti.	S2: (concuss* or mtbi* or «mild traumatic brain injur*» or «traumatic brain injur*» or post-concuss*).mp.	S2: (concuss* or mtbi* or «mild traumatic brain injur*» or «traumatic brain injur*» or post-concuss*)
Depression Anxiety Mood disorder/ psychiatric disorder Mood symptom / psychiatric symptom / psychiatric illness Low mood Mood outcome sequelae	S3: (depress* or anxi* or «mood disorder*» or «mood symptom*» or «low mood*» or «mood outcome*» or «psychiatric disorder*» or «psychiatric symptom*» or «psychiatric ill*» or sequelae).ab,kf,ti.	S3: (depress* or anxi* or «mood disorder*» or «mood symptom*» or «low mood*» or «mood outcome*» or «psychiatric disorder*» or «psychiatric symptom*» or «psychiatric ill*» or sequelae).mp.	S3: (depress* or anxi* or «mood disorder*» or «mood symptom*» or «low mood*» or «mood outcome*» or «psychiatric disorder*» or «psychiatric symptom*» or «psychiatric ill*» or sequelae)
	S1 AND S2 AND S3	S1 AND S2 AND S3	S1 AND S2 AND S3
Limits	Articles Published 2002 to 2022; Articles with abstracts; English language		