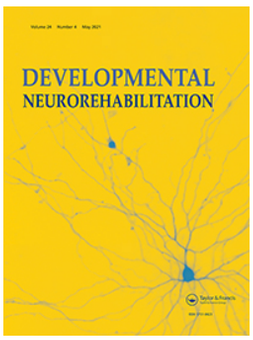

Developmental Neurorehabilitation

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ipdr20

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To cite this article: Brittany Wright, K. Wilmoth, S.B. Juengst, N. Didehbani, R. Maize & C.M. Cullum (2021) Perceived Recovery and Self-Reported Functioning in Adolescents with Mild Traumatic Brain Injury: The Role of Sleep, Mood, and Physical Symptoms, Developmental Neurorehabilitation, 24:4, 237-243, DOI: 10.1080/17518423.2020.1858456

To link to this article: https://doi.org/10.1080/17518423.2020.1858456

Published online: 24 Dec 2020.

DEVELOPMENTAL NEUROREHABILITATION
2021, VOL. 24, NO. 4, 237–243
https://doi.org/10.1080/17518423.2020.1858456

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Perceived Recovery and Self-Reported Functioning in Adolescents with Mild Traumatic Brain Injury: The Role of Sleep, Mood, and Physical Symptoms

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ABSTRACT

Purpose: To determine the contributions of anxiety, depressive, and concussion symptoms and sleep quality to self-perceived recovery in adolescents with concussion.

Method: Adolescents aged 12–20 (n = 298) completed anxiety, depression, concussion symptoms, and sleep measures at an initial concussion clinic visit and three-month follow-up. At follow-up, they reported self-perceived recovery as percent back to normal.

Results: Injury-related factors alone did not predict self-perceived recovery (R^2_{Adj} =.017, p =.074). More concurrent physical, mental health, and sleep symptoms explained 18.8% additional variance in poorer self-perceived recovery (R^2_{Adj} Change =.188, p <.05). Physical symptoms (B_{stand} = −.292) and anxiety (B_{stand} = −.260) accounted for the most variance in self-perceived recovery.

Conclusion: Post-concussive symptoms, in particular anxiety and self-reported physical symptoms, seem to characterize protracted recovery. Self-perceived recovery as an outcome measure may provide a more holistic understanding of adolescents' experiences after concussion.

ARTICLE HISTORY
Received May 18, 2020
Revised August 20, 2020
Accepted November 29, 2020

KEYWORDS
adolescent; mTBI; concussion; sleep; mood

Introduction

Mild traumatic brain injury (mTBI) represents one of the more common medical problems in the United States, with youth incidence being disproportionately higher than adults.[1] Moreover, mTBI is more likely to occur in adolescent youth (age 15–19) compared to other ages (5–14 years, 20–64 years),[2] with incidence in this age group increasing.[3] Though lasting physical, psychological, and social effects of mTBI among some adolescents have recently garnered significant media attention, persistent post-concussive symptoms are still poorly understood, even though as many as 20% of children who sustain a mTBI report symptoms lasting longer than three months.[4,5] Symptoms lasting beyond three months after mTBI are less likely to resolve and may be related to non-concussion factors[6,7] and result in chronic problems[8–10] that can negatively affect academic performance,[11,12] sleep patterns,[13] mood,[14] and quality of life.[12]

So-called "post concussive symptoms" are nonspecific, and distinguishing between premorbid versus post-injury factors that may be a result of or may be exacerbated by concussion presents challenges for researchers and clinicians. The most frequent persistent symptoms in adolescents with mTBI are changes in cognitive, emotional, and physical functioning, and in sleep quality.[15] In the general population, anxiety and depression are among the most common psychiatric disorders beginning in childhood, with anxiety occurring in approximately 2.2% and depression in approximately 11.7% of adolescents[16,17] After mTBI, up to one third of children experience a new-onset mood disorder and 1 in 5 an anxiety disorder, rates that are higher than after orthopedic injury.[18,19] Moreover, mood symptoms and somatization have been associated with prolonged recovery from pediatric mTBI.[20–22] There is evidence to suggest that somatization and poor adaptive functioning (i.e. based on social, functional, and communication-based skills), which co-occur with internalizing disorders, may delay post-concussive recovery in children with these psychiatric conditions.[21,23] Research also suggests that some individuals with a concussion may experience depressive symptoms as a result of psychosocial isolation during recovery. More specifically, adolescents may be affected by absences from school that influence peer relationships and lack of perceived social acceptance.[24] Poor sleep can also impact mood symptoms, i.e., depressive and anxiety symptoms,[25] but also behavioral and cognitive functioning, academic performance, and physical development[26–28] in adolescents. It remains difficult to distinguish emotional symptoms arising directly from mTBI from emotional symptoms secondary to academic or social challenges and other factors after injury.[29,30]

Post-concussive psychological disorders in youth may occur directly as a result of neurobiological consequences of mTBI.[31,32] The developing adolescent brain is highly sensitive to external and internal events, such as alterations in hormone levels, thoughts about bodily changes, and social interactions with others.[33] However, persistent post-concussion psychiatric symptoms may also be the result of pre-existing psychological factors.[34,35] Additionally, the physiological effects of mTBI can directly impact school performance and feelings of self-efficacy. Factors such as slower processing speed, more feelings of fatigue, lack of concentration, and persistent headaches can

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also contribute to lower productivity levels post-injury compared to pre-injury.[36] A combination of psychological symptomatology, self-concept, and a perceived decline in academic functioning may lead adolescents to believe – or self-perceive – that they are not fully recovered from a mTBI.

While some research examines predictors of recovery from mTBI, few studies focus on adolescents' self-perceived recovery. Recovery is most often measured through return to school, return to play, or return to baseline physical or cognitive performance.'[37,38] Measures that capture self-perceived recovery, which may be more directly influenced by psychological consequences of mTBI, may better predict who is at higher risk for persistent symptoms and poor functioning. Injured individuals who do not show objective neurocognitive or physiologic abnormalities more than a few days following injury[39–41] may still go on to report persistent post-concussive symptoms. Predominantly used measures (i.e. cognitive and physical functioning) may not be enough to fully capture these symptoms.

Psychological factors, including depression, anxiety, and sleep disturbances, have been identified as potential predictors of chronic symptoms after mTBI.[42–44] Interventions to address these psychological symptoms early after injury may improve recovery trajectories. Though research has documented the significant impact of childhood mTBI on physical and cognitive sequelae, little research has focused on psychological symptoms.[30] Few studies have assessed anxiety symptoms and prolonged recovery as a result of mTBI[30,45] or looked at mood symptoms as a result of concussion.[46,47] To address this gap in the literature, the purpose of the present study was to examine the relationship of depressive symptoms, anxiety, physical symptoms, and sleep quality to self-perceived recovery at three to four months after mTBI among adolescents. By examining self-perceived recovery or "feeling back to normal" as an outcome, we can better understand exactly which factors, whether injury-related or factors such as sleep, mood, or physical symptoms, contribute to return to pre-injury functioning. We evaluated these relationships between physical, psychological, and sleep factors and self-perceived recovery in a multisite, prospective study of individuals presenting to concussion clinics.

Methods

Participants

The present study was a secondary analysis of data from the [North Texas] Concussion Registry [ConTex]. [ConTex] was designed to capture longitudinal data on individuals with mTBI recruited from collaborating outpatient clinics [UT Southwestern Medical Center, Children's Medical Center, Texas Scottish Rite Hospital for Children, and Texas Health Resources]. A detailed protocol was previously published.[48] Briefly, participants were included if they were English-speaking adolescents aged 12–20. Participants were excluded from the registry study if they were not diagnosed with a concussion upon their initial clinic visit, had a visual or hearing impairment, were unable to provide assent, were not fluent in English, were diagnosed with a moderate-severe TBI, or had a spinal cord injury ASIA score of C or worse. Participants with a history of previous head injury were included. For the current analysis, participants had to have presented for an initial clinic visit 0–30 days after injury and subsequently completed 3-month follow-up. This range was selected because it reflects the acute/subacute post-injury period and multiple studies have established that symptoms lasting beyond 30 days may result in a diagnosis of "post-concussive syndrome" and should be monitored clinically.[10,32]

Procedure

Participants were consented at an initial concussion clinic visit less than 6 months after their index mTBI and were contacted again three months after their initial clinic visit. For the purposes of the current study, only participants within 30 days of initial injury were included in order to more effectively control for time since injury. Participants completed a battery of measures capturing personal and medical history, injury-related information, and symptoms at the initial clinic visit. They are emailed a link via RedCap™ at 3-month follow-up, via which they completed many of the same measures. A detailed description of all measures was previously published.[48]

Measures

Standard medical history and injury information were collected across [collected across sites] sites (see reference 48 for details). At the initial clinic visit, participants completed the Sports Concussion Assessment Tool – Third Edition (SCAT-3) symptom evaluation,[49] Patient Health Questionnaire 8-item depression scale (PHQ-8),[50] General Anxiety Disorder-7 (GAD-7) anxiety scale,[51] and Pittsburgh Sleep Quality Index (PSQI).[52] The SCAT-3, a physical symptom evaluation that is identical to the SCAT-5, is scored based on the total raw score, and has been validated in adolescents with mTBI.[53] The PHQ-8, GAD-7, and PSQI have been validated in adolescents[54–56] and those with TBI[57–59] separately. The PHQ-8 is a depression screening tool with a cutoff score of greater than 10 indicating moderate depressive symptoms.[50] The GAD-7 is a brief anxiety measure with scores greater than 10 indicating moderate anxiety symptoms.[51] The PSQI is a measure of overall sleep quality and seven domains that may affect sleep. A composite score of 5 or greater on the seven domains indicates poor sleep.[52] Participants were also interviewed about the characteristics of their injury, as well as more broadly about their overall medical history. Three months after the initial clinic visit, participants repeated all measures via electronic survey (RedCap™).[60] For this study, 3-month sleep quality (PSQI), anxiety (GAD), depressive symptoms (PHQ), and self-reported physical symptoms (SCAT-3) were the main predictors in addition to injury-related and demographic factors such as age, LOC, gender, time since injury, and previous head injury. Self-reported recovery is our main outcome measure and was assessed as "percent back to normal" at both the initial visit and three-month follow-up. Participants rated on a 0–100% scale their response to the following question: "*What percentage back to normal are you compared to before the concussion?*" For the GAD, SCAT-3, and PHQ, total raw scores were used in the

analysis and the PSQI composite score was calculated based on the sum of the individual domain scores.

Statistical Analyses

We present descriptive statistics (frequencies and percentages or means and standard deviations) for demographic and clinical measures for the study sample. We conducted a hierarchical linear regression to determine the effects of commonly used predictors (age, sex, loss of consciousness, time since injury, previous head injury) and concurrent physical symptoms, depressive symptoms, anxiety symptoms, and sleep quality on self-perceived recovery (i.e. return to normal). The base model included common predictors, the second level included physical post-concussive symptoms (SCAT-3), and the third level added depressive, anxiety, and sleep symptoms. This approach allowed us to determine the unique and additive contribution of each of these symptom domains to self-perceived recovery. We set an alpha level of .05 for statistical significance and checked all statistical assumptions including multicollinearity with variance inflation factors <5 for each of the variables. Analyses were conducted using IBM SPSS for Windows and Mac, version 26.

Results

Participant Characteristics

Table 1 summarizes demographic and clinical measures for the sample.Participants (n = 298) were on average 15.1 (SD = 1.8) years old, 52% female, 15% Hispanic or Latino, and 81% White, and all were diagnosed with concussion by an experienced health-care provider in one of our [ConTex] clinics. The most common mechanism of injury was sport (79%), and 16% experienced a loss of consciousness. At their 3-month follow-up after initial clinic visit (M days since injury = 9.51, SD = 7.32 days, range: 0–30 for initial clinic visit), participants were asked the extent to which they perceived themselves to be "back to normal" on a scale of 1–100. Overall, participants reported improvement in symptoms from the initial clinic to the three-month follow up on measures of anxiety, depression, sleep, and physical symptom reports (see Table 1).

Linear Regression

The hierarchical linear regression determined the extent to which factors including age, time since injury, loss of consciousness, sex, previous head injury, and three-month total scores on clinical symptom measures (SCAT, GAD-7, PSQI, and PHQ-8) predicted self-perceived recovery. Table 2 presents all results for the hierarchical linear regression. The base model included age, LOC (Y/N), sex, time since injury, and previous head injury (Y/N) in order to assess the contributions of commonly used predictors on perceived recovery. This base model was not significant when assessed independently (p = .074) and these factors only accounted for 1.7% of the variance in self-perceived recovery. Physical symptoms at three-month follow-up accounted for an additional 16.5% of the variance (p < .001). Psychological and sleep measures (i.e. PHQ, GAD, and PSQI) accounted for an additional 2.3% of the variance (p < .05). However, the standardized β for the SCAT 3-month scores changed substantially from −.421 to −.292

Table 1. Descriptive statistics.

Factor	Mean (±SD)
Age (Years)	15.1 (1.8)
Education (range 5–14 years)	9.0 (1.7)
Days from injury to initial visit*	9.5 (7.3)
Percent back to normal	
Initial total score	64.8 (23.6)
3-Month total score	92.3 (15.6)
Anxiety (GAD7)	
Initial total score	3.7 (4.4)
3-Month total score	2.0 (3.8)
Depression (PHQ8)	
Initial total score	4.5 (4.6)
3-Month total score	1.7 (3.3)
Sleep (PSQI)	
Initial total score	4.4 (2.9)
3-Month total score	3.9 (3.1)
Symptom Log	
Initial total score	27.6 (24.4)
3-Month total score	6.3 (15.3)
	n (%)
Gender (female)	156 (52.3)
Race (white)	240 (80.5)
Mechanism of injury	
Sports-related	235 (78.9)
Motor vehicle accident	20 (6.7)
Fall	1 (0.3)
Hit by an object/hit an object	26 (8.7)
Assault	16 (5.4)
Loss of consciousness (yes)	49 (16.4)
Post-traumatic amnesia (present)	86 (28.9)
Previous psychiatric disorder	38 (12.8)
Previous head injury	96 (32.2)

*Time since injury to initial visit restricted to those within 30 days.

Table 2. Hierarchical linear regression analyses for the effects of commonly used predictors and measures on perceived recovery (n = 298).

	Perceived Recovery Model 1			Perceived Recovery Model 2			Perceived Recovery Model 3	
	β_{stand}	P		β_{stand}	P		β_{stand}	P
Intercept	-	<.001	Intercept	-	<.001	Intercept	-	<.001
Age	−.110	.061	Age	−.033	.550	Age	−.014	.791
Sex	.058	.315	Sex	.007	.902	Sex	.005	.928
LOC	−.114	.049	LOC	−.089	.092	LOC	−.091	.081
Time since injury	−.020	.732	Time since injury	.004	.944	Time since injury	.022	.684
Previous head injury	−.042	.473	Previous head injury	−.010	.848	Previous head injury	−.002	.969
			3 Month Sx Log Score	−.421	.000	3 Month Sx Log Score	−.292	.000
						3 Month GAD Score	−.260	.007
						3 Month PHQ Score	.135	.216
						3 Month PSQI Score	−.097	.181
	R^2=.034	.074		R^2=.199	<.001		R^2=.229	<.001
	R^2_{Adj} =.017			R^2_{Adj} =.182			R^2_{Adj} =.205	
				$R^2\Delta$ =.165	<.001		$R^2\Delta$ =.030	.011
				$R^2_{Adj}\Delta$ =.165			$R^2_{Adj}\Delta$ =.023	

R^2 Δ for 3 Month Sx Log Score ($F_{1,291}$ Δ = 59.852, P<.001); R^2 Δ for 3 Month GAD, PHQ, and PSQI ($F_{3,288}$ Δ = 3.780, P<.05).

from Model 2 to Model 3, and the standardized β for Anxiety was the second highest at −.260, suggesting that physical symptoms in Model 2 may have been capturing shared variance with Anxiety.

Discussion

Perceived Recovery and Injury-Related Factors, Physical Symptoms, Mood, and Sleep

Adolescents with concussion reported improvement on physical, sleep, and emotional measures and in self-perceived return to normal from the initial clinic visit to the three-month follow-up. Commonly used predictors of recovery alone did not fully account for variability in self-perceived recovery. While injury-related factors are important to consider when diagnosing and treating a concussion and for immediate symptom severity, past research suggests inconsistencies in the predictive power of these factors for persistent symptoms.[38] Concurrent concussion symptom log scores were more strongly associated with self-perceived recovery, indicating that persistent physical symptoms are important. However, physical symptoms may highly overlap with anxiety, as indicated by the change in effect size for physical symptoms when adding anxiety to our model. The significance of anxiety and the variance that this measure accounted for relative to physical symptoms indicates the potential overlap between somatic and cognitive symptoms on the SCAT and anxiety-related symptoms endorsed by the participants. This aligns with prior research that symptom recovery is linked to somatization tendencies in adolescent and early adult concussion,[61,62] and that psychological factors may be highly relevant to self-perceived recovery.

The Importance of Evaluating Self-Perceived Recovery

Understanding what factors lead adolescents to feel as if they have not returned fully to pre-injury functioning is necessary for targeting treatments for these individuals. Including self-reported measures of recovery after mTBI may capture unresolved problems that are not otherwise captured by objective measures, like neuropsychological tests. Our study illustrates a potentially complex constellation of emotional symptoms, in addition to physical symptoms, that adolescents with mTBI experience beyond the scope of physician-based physical and cognitive reports. Moreover, our results specifically indicate that self-reported post-concussive and psychological symptoms may have utility in determining who is experiencing prolonged symptoms and that screening for psychological symptoms is necessary when treating adolescents who have sustained a mTBI.

Clinical Implications

Concussion is an increasingly important public health concern, with high incidence rates that are likely conservative due to a lack of reporting or diagnosis.[63] The complex factors contributing to mTBI outcomes are not fully understood, often making diagnosis and subsequent care difficult.[64] On the other hand, concussion has been recently garnering more attention, which may result in increased clinic visits and potential over-reporting of symptoms.[65,66] Although physical symptom reporting and scores on cognitive measures are often used as benchmarks of measuring recovery, individuals' perceptions of their recovery process are often overlooked. Variability in the experience, definition, and measurement of recovery also makes it difficult to predict who is more likely to experience persistent post-concussive symptoms. Using measures of self-perceived recovery may be beneficial in determining who is more likely to experience these symptoms.[67] Our research highlights the complexity of mTBI recovery, as we have shown that self-reported physical and psychological symptoms may overlap and are indicative of return to pre-injury functioning. While cognitive functioning may be similar in those who have sustained a mTBI compared to healthy controls, these individuals still may experience more emotional symptoms[68] indicating a need for assessment of other factors besides physician-based assessments of ability to return to school or play. Understanding how some individuals' perceptions of their recovery are affected by their emotional

symptoms following mTBI may mitigate the effects of contributing symptoms and shorten recovery time.[69]

Because adolescents are in a developmental stage in which their brains are still developing and they are actively forming their self-concept, aspects of their symptoms and recovery may be unique compared to other age groups. Research suggests that identity formation may be a factor stifled by brain injury and that the different domains of interpersonal functioning and academic performance play a key role in self-concept formation.[30,70] Moreover, academic performance, participation in physical activities, and positive parental interaction styles have all been associated with higher self-esteem in adolescents.[71] Hence, returning to pre-injury activities with the appropriate accommodations and supports may be beneficial to continued self-esteem and identity development after mTBI. If adolescents are perceiving themselves as not fully recovered, then this may impact them academically and socially, as well as emotionally. Returning to pre-injury functioning is likely contingent on perceived recovery and feelings of self-efficacy in these adolescents, similar to what is observed in adults with TBI.[72] By utilizing the concept of "perceived recovery" in the future, researchers may be able to understand which areas are the most impacted in the lives of those who have sustained mTBI and address these with tailored rehabilitation efforts.

Limitations

Our study contained predominantly White participants from a single metroplex and this may not be representative of individuals with a mTBI or TBI more broadly across the United States.[73,74] However, results from our sample indicated no differences between recovery groups on the basis of race. Our study consisted of mostly athletes that had sustained a sports-related concussion (79%), and therefore may not reflect other mechanisms of injury. Additionally, the current study lacks a comparison group of individuals without TBI. However, the goal of this research was to assess the utility of measuring perceived recovery above and beyond injury to better understand how self-perceived recovery may be associated with many different factors (in those with mTBI specifically). The clinical relevance lies in the complex constellation of many different factors that contribute to persistent feelings of being "not 100% back to normal." Despite these limitations, our data convey the importance of evaluating emotional symptoms after mTBI and the need for further research into other factors that may be affecting adolescent recovery following mTBI.

Future Implications

This study should be replicated in a more diverse population in order to better understand emotional and behavioral functioning following mTBI across different demographic strata. Like most other research conducted in this area, our study included only English speakers, excluding a growing demographic of Spanish speakers in the United States. However, we are working to adapt our measures for Spanish speakers to allow for better representation. Moreover, using emotional symptom measures may be important to understand perceived levels of recovery, and these factors may vary along sociodemographic lines. Fully understanding the interaction between psychological symptoms and other factors may be difficult as mood symptoms can impact many areas of daily life. This is why careful attention should be given to creating and validating measures to assess the impact of psychological factors and internal perceptions of recovery, particularly measures specific to adolescents and their unique developmental stage.[75,76] Adolescent self-report measures that address psychological symptoms as well as perceived functioning would likely better capture adolescent functioning more holistically, beyond an examination of post-concussive symptoms, cognitive functioning, or physical symptoms. Future work should explore individuals' perceptions of recovery through more multi-dimensional measures (i.e. physical functioning, emotional health, cognitive abilities, etc.).

Funding

This work was supported by the Texas Institute for Brain Injury and Repair (TIBIR), a state-funded initiative as part of the Peter J. O'Donnell Jr. Brain Institute at the University of Texas Southwestern Medical Center.

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