Predictors of Recovery from

Pediatric Concussion

by

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ABSTRACT

Concussion, or mild traumatic brain injury (mTBI), is a frequent cause of brain damage among youth and, therefore, represents a major public health problem. While most youth recover from concussion within 2 to 4 weeks, some concussed children and adolescents endure prolonged symptoms, along with mood disturbance sequelae for months. Few studies have assessed mood disturbance and concussion in pediatric populations. Additional research is necessary to understand pediatric concussion recovery and mood disturbance better, to guide early intervention efforts, and to improve pediatric concussion care. The purpose of this study was to examine how symptoms of mood disturbance (i.e., anxiety, depression, anger) and somatization relate to the odds of concussion recovery in male and female youth 12 to 17 years of age, who presented for neuropsychological evaluation after head injury. Significantly fewer females were deemed recovered at initial neuropsychological evaluation compared to males. Bivariate analyses of mood disturbance and somatization predictors revealed significant group differences in symptom burden between those determined recovered from concussion and those who had not recovered. Logistic regressions of each mood disturbance variable and somatization on concussion recovery suggested a modest decline in the odds of recovery as symptoms of mood disturbance or somatization increase. A multivariable logistic regression model of mood disturbance predictors, somatization, gender, and age was significant and explained over a quarter of the variance in concussion recovery; however, after a backward variable selection procedure, only depression and somatization symptoms were significant in the final model and accounted for a modest decline in the

odds of concussion recovery at initial evaluation. Results replicate and extend research findings in pediatric concussion.

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CHAPTER 1

INTRODUCTION

Traumatic brain injury (TBI) is a frequent cause of brain damage among children and adolescents (Langlois et al., 2006; Lezak et al., 2012), and represents a major public health problem. As many as one in five children will sustain a TBI by the age of 16 years old (Barlow, 2016). A TBI, "…generally refers to an injury involving the brain resulting from some type of impact and/or acceleration/deceleration of the brain" (Lezak et al., 2012, p. 180). Concussion is one of the mildest forms of TBI (Lezak et al., 2012).

In North America, over one million cases of pediatric concussions are treated each year (Moore et al., 2018) and worldwide estimates indicate 33 million cases of pediatric concussion are treated annually (Davis et al., 2017). While most youth recover from concussion symptoms within 2 to 4 weeks (Ledoux et al., 2019), between 10% and 29% of concussed children and adolescents endure prolonged symptoms along with mood disturbance sequelae for three months or longer duration (Barlow, 2016; Brent & Max, 2017; Ledoux et al., 2019). This can negatively impact pediatric academic outcomes and quality of life. Mood disturbances, such as anxiety and depression, appear to be hallmarks of post-concussion syndrome in adults (Guskiewz et al., 2007; Mainwaring et al., 2012). Few studies have assessed the mental health outcomes of concussion in pediatric populations. Additional research is necessary to understand pediatric concussion recovery and mood disturbance better, to guide early intervention efforts, and to improve pediatric concussion care.

The purpose of this study was to explore the impact of mood disturbance, somatization, and gender on the odds of concussion recovery in adolescents aged 12 to 17 years old. In the following review, background information on concussion including definitions, symptoms, pathophysiology, and outcomes associated with concussive injuries are provided. Then, the relationship between mood disturbance and concussion is discussed. Next, the literature on concussion outcomes related to age, sex/gender differences, and somatization is reviewed, and the research questions and hypotheses formulated.

CHAPTER 2

BACKGROUND LITERATURE

Overview of Concussion

Concussion research has received significant publicity in recent years, but the bulk of studies have centered on adults. More research on the outcomes of concussion in the pediatric population is critical as brain injury during a period of critical brain maturation carries heightened risk for detrimental outcomes (Barlow, 2016). Concussion is characterized as a biomechanically induced mild traumatic brain injury (mTBI) with functional, physiological, and symptomatic changes unaccompanied by structural changes (Brent & Max, 2017; Kerrigan & Giza, 2017). The symptomatic presentation of a concussion involves interrelated symptoms, such as disturbances in cognition, affect, mood, and sleep (Barlow, 2016; Brent & Max, 2017). Falls, recreational accidents, and sports-related accidents are the most common causes of concussive injury (Barlow, 2016).

Definition and Terminology. The term "concussion" is not well defined in either clinical or research settings. The diagnosis of concussion is frequently substituted for other related medical terms, such as minor closed head injury, mild closed head injury, and mild traumatic brain injury (mTBI) (Apps & Walter, 2012). There seems to be a greater tendency to use the term concussion for injuries sustained in the sports community and a tendency to use the term mTBI in medical settings (Apps & Walter, 2012).

In addition to different terms used to describe concussive injuries, there are numerous definitions of concussion. Although the definitions put forth by the World

Health Organization and the International Statistical Classification of Diseases and Related Health Problems (ICD-10) are two of the most widely used definitions of concussion (Barlow, 2016), the Committee on Quality Improvement and Pediatrics (1999) created a definition of a minor closed head injury in the pediatric population:

> …children with a minor closed head injury [are] those who have normal mental status at the initial examination, who have no abnormal or focal findings on neurologic (including fundoscopic) examination, and who have no physical evidence of skull fracture (such as hemotympanum, Battle's sign, or palpable bone depression)…who may have experienced temporary loss of consciousness (duration 1 minute) with injury, may have had a seizure immediately after injury, may have vomited after injury, or may have exhibited signs and symptoms such as headache and lethargy. (pp. 1407-1408)

This definition and the term minor closed head injury make it clear that a brain injury occurred. However, due to the diversity in the terms and definitions for concussive injuries, there is often confusion amongst patients and their families about the seriousness of a concussion. DeMatteo (2010) found that when the term concussion was utilized with patients and their families to describe a mild traumatic brain injury, patients and families were less likely to follow-up with medical providers; therefore, DeMatteo (2010) suggested using terms that indicate a brain injury had occurred, such as mild traumatic brain injury.

Many definitions of concussion exist, but critical components of the definition are similar. A concussion typically results in a "rapid onset of short-lived impairments in neurologic function" and neuropathological changes that generally "reflect a functional disturbance rather than a structural injury" (Lezak et al., 2012, p. 183). In essence, concussion is defined as a biomechanically induced mild traumatic brain injury (mTBI) with functional physiological and symptomatic changes unaccompanied by structural changes (Brent & Max, 2017; Kerrigan & Giza, 2017). Recovery times vary with concussive symptoms tending to resolve within days or weeks, whereas post-concussive symptoms are prolonged for some individuals (Barlow, 2016; Ledoux et al., 2019).

Symptomatic Presentation. The symptomatic presentation of a concussion is heterogeneous, and symptoms are interrelated. Symptoms are usually short lived but may evolve over minutes to hours (Ledoux et al., 2019; Kerrigan & Giza, 2017). Immediately following a concussion, the head injured person may exhibit visible signs of confusion, amnesia, vomiting, lack of coordination, and unsteady gait. Some level of amnesia, either anterograde or retrograde, is much more common than a loss of consciousness, which only occurs in about 10% of injuries (Ledoux et al., 2019; Kerrigan & Giza, 2017). Potential symptoms of concussion include disturbances in cognitive abilities (e.g., concentration, memory, and executive functions), physical abilities (e.g., headaches, nausea), sensory abilities (e.g., double vision, phonophobia, photophobia), mood (e.g., irritability, sadness, emotional lability), and sleep (e.g., difficulty with sleep onset; Barlow, 2016; Brent & Max, 2017). According to some studies, the majority of pediatric concussion patients experience resolution of acute symptoms between seven and 10 days (Barlow, 2016; Brent & Max, 2017). However, Ledoux et al. (2019) found children required approximately 2 weeks for symptom improvement and adolescents required approximately 4 weeks for symptom improvement in a multicenter cohort study of almost 3,000 pediatric patients recovering from concussion. While the symptoms observed in and experienced by children and adolescents are frequently similar to those of adults, parental reporting to medical professionals is often necessary for a full report of frequency and severity of symptoms.

Pathophysiology. Significantly, child and adolescent concussions occur during a period of maximal brain development, when the brain is susceptible to trauma (Barlow, 2016). During childhood, the brain has a higher water content and a lower myelin content than what is observed in emerging adults and adults. Additionally, children and adolescents do not have the mature neck strength of their adult counterparts. Their necks cannot withstand forces of acceleration-deceleration as sturdily as adults do, which places them at greater risk for head injury (Barlow, 2016). Children and adolescents may experience changes in their brain energy states, changes in cerebral blood flow, and neuroinflammation (Barlow, 2016).

Historically, concussion has been viewed as an injury due to rotational shear forces and acceleration and deceleration forces on the brain that result in the destruction or sheering of neuronal axons (Apps & Walter, 2012). However, concussion is not just diffuse axonal injury from a neurophysiological standpoint. The clinical manifestation of concussion symptoms result from sequential neuronal dysfunction due to ionic shifts, altered metabolism, impaired connectivity, or changes in neurotransmission (Barkhoudarian et al., 2016; Giza & Hovda, 2001). Collectively, the underlying pathophysiological processes of concussion have been characterized as a neurometabolic cascade (Barkhoudarian et al., 2016; Giza & Hovda, 2001), with shifts in brain chemistry leading to symptomatic presentation.

Long-Term Outcomes. A concussion may affect the child and adolescent brain in various ways in the long term. Functional connectivity of the brain may be impaired, meaning that the speed of neuronal communication may be decreased, and cerebral blood flow may become altered after a concussion (Moore et al., 2018). Children and adolescents may experience sensory and motor deficits after concussion, such as changes in vision, hearing, or fine motor skills (Moore et al., 2018). Specific cognitive abilities may take additional time to return to normal including attentional inhibition and cognitive flexibility (Moore et al., 2018). A growing body of research on pediatric sports-related concussion demonstrates that pediatric concussion can alter aspects of higher cognition (i.e., attention, executive function, memory) beyond the acute phase of injury, and those injured earlier in development may exhibit the worst outcomes (Barlow, 2016; Moore et al., 2018). Deficits in executive functions (i.e., inhibition, mental flexibility, working memory) appear to be the hallmark of pediatric concussion.

Post-Concussion Syndrome. Barlow (2016) reported that one in seven children experience post-concussion syndrome for three months or longer after a mild traumatic brain injury. Post-concussion syndrome (PCS) is essentially a prolonged recovery from concussion. The term 'post-concussion syndrome' does not have a defined set of criteria in the pediatric population. However, Barlow (2016) conducted a study with a pediatric sample and found the following definition of PCS to be predictive of a diagnosis in youth:

> "Post-concussion syndrome following mild traumatic brain injury is (a) a history of mild traumatic brain injury with an onset of symptoms or signs within 72 hours of the injury, (b) the presence of at least 3 of the following symptoms: headache,

dizziness, fatigue, irritability, insomnia, difficulty concentrating, memory problems, emotional lability, and mood disturbance, (c) symptoms have been present for at least 4 weeks post injury, and (d) symptoms are not better explained by another disorder" (p. 59).

The symptoms of PCS represent a significant burden for youths. Most youth make a full recovery from PCS, although recovery may take up to several months.

Mood Disturbance and Concussion

In concussion research on the adult population, psychological changes are an indicator of PCS and an early indicator of neurodegeneration (Mainwaring et al., 2012). In a review of the impact of concussion on collegiate age and older athletes, Mainwaring and colleagues (2012) found that: "Depression, fatigue, irritability, confusion, and general mood disturbance are frequently reported after cerebral concussion in sport" (p. 247). In an earlier study on mood and concussion, Mainwaring et al. (2004) found that 14 days after concussion, athletes reported more depression, confusion, and overall mood disturbance as compared to controls. Mood disturbances tended to resolve within three weeks after injury. Furthermore, Sandel, Reynolds, and colleagues (2017) proposed six clinical profiles for those recovering from sports-related concussions, including an anxiety and mood profile characterized by "ruminative thinking, hypervigilance, anxiety, panic, depressed mood, apathy, sleep disruption, and symptom endorsement on psychological inventories" (p. 305).

Depression and Anxiety. In concussion research, depression and anxiety have emerged as two significant components of concussion-related mood disturbance. Symptoms of depression include a depressed mood, loss of interest or pleasure, weight changes, sleep changes, psychomotor changes, fatigue, feelings of worthlessness, feelings of guilt, decreased ability to concentrate and make decisions, as well as thoughts of dying or suicide (American Psychiatric Association, 2013). Symptoms of anxiety include worry and apprehensive expectation accompanied by restlessness, fatigue, difficulty concentrating, irritability, muscle tension, and sleep disturbance (American Psychiatric Association, 2013). The symptoms of depression and anxiety often co-occur and frequently overlap with acute symptoms of concussion as well as PCS (Bloom et al., 2004; Iverson, 2006).

Some researchers have proposed that there are neuroanatomical underpinnings to mood disturbance following concussion (Chen et al., 2008; Covassin et al., 2017). Mechanically, when an individual endures a concussion, there is an acceleration-deceleration injury to the brain that occurs in a coup or contrecoup fashion. A coup brain injury occurs in the same area of the brain as skull impact (Lezak et al., 2012). For example, if the initial impact were on the forehead area of the skull, the brain area directly behind the forehead, the prefrontal lobe, would sustain a coup injury as it hit the skull behind the forehead. A contrecoup injury results when a brain injury occurs on the opposite side of the initial skull impact (Lezak et al., 2012). To continue with the previous example, a contrecoup injury would occur to back area of the brain, the occipital lobe of the brain, after the brain made impact with the skull behind the forehead and bounced back against the back part of the skull. Associated damage may occur as cortical contusions and abrasions or diffuse axonal injuries in brain regions (Covassin et al., 2017). Concerning anxiety, the neuroanatomical underpinnings most likely involve over-activation of the behavioral inhibition system, which includes the septohippocampal system, thalamus, prefrontal cortex, cingulate cortex, locus coeruleus, and the papex circuit (Gray, 2019). In regard to depression, homeostatic emotional control may be disrupted by injuries to the limbic cortical regions, which is seen in individuals who have clinical depression. When compared to concussed athletes who were not depressed, athletes who were concussed and depressed showed reduced activity in the dorsolateral prefrontal cortex and striatum as well as weakened deactivation in the medial frontal and temporal regions on fMRI assessment. Moreover, depression severity was inversely related to the density of gray matter (i.e., neuronal cell bodies and dendrites) in these brain regions (Chen et al., 2008). These findings are again consistent with fMRI findings in patients with depression (Mainwaring et al., 2012).

In the adult concussion population, depression has been studied frequently. Mainwaring et al. (2012) found that depression following concussion in adult athletes tended to resolve within 30 days. Depressed mood seems to endure for the duration of the pathophysiologic response, which involves neurometabolic changes and shifts in brain chemistry (Barkhoudarian et al., 2016; Giza & Hovda, 2001). Additionally, concussions have been associated with risk for depression later in life. Guskiewicz et al. (2007) conducted a retrospective study on retired football players and found a dose-response relationship between depression and the number of previous concussions; for example, those football players with one to two concussions were about 1.5 times more likely to have received a diagnosis of depression, and those with three or more concussions were about 3 times more likely to have received a diagnosis of depression. College students with a history of repeated mTBI also showed a dose-response relationship between the number of lifetime mTBIs and self-reported history of depression (Vynorius et al., 2016).

Additionally, Yang and colleagues (2015) found that more than one third of athletes who sustain concussions at the college level also experience symptoms of anxiety.

The existing research on pediatric concussion suggests that youth who sustain concussions are at risk for mood disturbance, but more research is needed. Sariaslan and colleagues (2016) found that youth with a history of concussion reported more socio-emotional stress than uninjured controls. In a study on very young children with mTBI, Liu and Li (2013) found that children who had a history of more than one mTBI compared to controls had a higher risk for mood disturbances and behavioral difficulties. Relatedly, several research studies now suggest that youth who incur a concussion may also be at an increased risk for a new onset psychiatric disorder following concussion in both the short-term and the long-term (Ellis et al., 2015; Massagli et al., 2004; Max et al., 2013). Furthermore, research using metanalyses also suggested increased incidence of mood disturbances, anxiety, and depression in pediatric samples with concussion compared to their uninjured counterparts (Emery et al., 2016; Keightley et al., 2014).

Anxiety and depression, in particular, appear to be related to concussion recovery. Children with premorbid anxiety tend to take almost twice as long to recover from concussion symptoms than children without a premorbid history of anxiety (Corwin et al., 2014). Moreover, when compared with children whose concussion symptoms remitted within one week, children with concussion symptoms lasting longer than one month reported more symptoms of anxiety (Grubenhoff et al., 2016). In a prospective study, Kontos and colleagues (2012) found that youth who had endured a concussion, as compared to non-concussed controls, showed higher levels of depression up to 14 days after injury. After the acute phase of concussion symptoms, children who sustain a concussion may be at increased risk for depression later in their lives. Chrisman and Richardson (2014) conducted a retrospective pediatric cohort study examining the relation between current depression symptoms and a past concussion. For those children with a history of concussion, the risk for depression symptoms was over 3 times greater than for noninjured children.

Anger. For individuals with moderate to severe traumatic brain injury (TBI), irritability and anger are frequent, and sometimes, life altering post-injury symptoms (Lezak et al., 2012). In addition to the emotional symptoms of anxiety, depression, distress, and shock reported following concussion, anger is a commonly reported emotional symptom, especially after a sport-related concussion (Bloom et al., 2004). In a cross-sectional study with former collegiate athletes who suffered recurrent concussions, Kerr and colleagues (2014) found a relation between heightened risk of aggression, impulsivity, and severe depression in those with a history of concussions, even after accounting for confounding variables such as sex, alcohol dependence, and relationship status.

In the literature, there is some support for brain differences in anger-related mood disturbance after concussion, especially for males. Moore and colleagues (2016) utilized electroencephalograms (EEG) to examine the psycho-affective outcomes of concussive injuries in young-adult male athletes with a history of concussion. All participants in the concussion group had been symptom-free from concussion for 9 months and had returned to playing their sport; the control group participants were athletes without a history of concussion. Results indicated that while athletes denied symptoms of concussion, specifically emotional symptoms, neural activity was consistent with psycho-affective disturbances. Results indicated participants with a history of concussion demonstrated significant differences in their frontal-beta and frontal-alpha asymmetries when compared to the control group. Further correlational analyses indicated that the changes in frontal-beta asymmetry were associated with self-reported aggression and anger, while the changes in frontal-alpha asymmetry were associated with self-reported anxiety and depression (Moore et al., 2016).

A few studies with youth also reveal the risk for anger and irritability after concussion. Hunt (2015) used a qualitative design to examine the psychological outcomes following concussion in youth aged 13 to 18 years old. Analysis of transcribed semi-structured interviews revealed that adolescents were enduring increased symptoms of anger; moreover, feelings of anger were related to feelings of frustration and boredom during recovery. Provvidenza and colleagues (2013) conducted a qualitative study regarding the life impact of sports-related concussion with a predominantly male adolescent sample and parents were also included in the study. Framework analysis of semi-structured interviews with the adolescents and their parents revealed higher levels of anger and frustration related to school performance post-injury.

Potential predictors of pediatric concussion recovery and mood disturbance include sex, gender, age, and somatization. A few studies suggest that females tend to have increased risk for developing mood disturbances, greater post-concussion symptoms, and more prolonged recovery times after concussions (Crowe et al., 2016; Thomas et al., 2018; Zemek et al., 2016;). Compared to both younger children and adults, adolescents with mTBI tend to take longer to recover (Nelson et al., 2016; Zemek et al., 2016; Zuckerman et al., 2012). Higher scores on somatization assessments have been linked to prolonged concussion recovery (Grubenhoff et al., 2016; Root et al., 2016).

Age

A majority of the research on concussions has included adult and collegiate populations as participants. It is crucial to evaluate whether findings on adult concussions generalize to the pediatric population. When pediatric populations are compared with adults, there are significant physical and neurological differences that contribute to the likelihood of sustaining a concussion and longer recovery time after concussion (Barlow, 2016). Physical differences include neck strength and skull thickness, while neurological differences include brain size, cerebral blood flow, and myelination (Kirkwood et al., 2006). Furthermore, adolescents appear to experience the most prolonged recovery period from concussion.

In one of the few studies that has incorporated age as a predictor of recovery with pediatric patients, Zuckerman et al. (2012) assessed recovery from sports-related concussion in a pediatric to emerging adult aged sample (i.e., aged 13 to 22 years old). While most of the patients recovered to baseline levels of post-concussive symptoms within a week, adolescents aged 13 to 16 years required approximately two more days to recover than did the emerging adults aged 18 to 22 years. Furthermore, the same trend was observed in recovery from neuropsychological symptoms of concussion. Adolescents required approximately two more days to return to cognitive baseline than the emerging adults. In a study on concussed high school and collegiate athletes compared to non-injured controls, Nelson and colleagues (2016) found that the participants in the high school age group required about 1.5 days longer to score in the recovered range on the

Standardized Assessment of Concussion, an assessment tool that measures Orientation, Immediate Memory, Concentration, and Delayed Memory Recall. In a prospective study on 296 male and female high school and college athletes, Covassin and colleagues (2012) identified differences in post-concussive symptoms and cognitions for students who were assessed at baseline and then again assessed at 2, 7, and 14 days post-concussion. High school aged participants performed worse than their older collegiate athlete counterparts in the cognitive areas of verbal and visual memory (Covassin et al., 2012). Within a month of injury, high school aged athletes frequently resume their cognitive baseline of functioning, (Collins et al., 2002; McCrea, Hammeke, et al., 2004). However, college aged athletes (i.e., emerging adults) returned to their cognitive baselines in approximately one week to 10 days (Collins et al., 1999; McCrea, Guskiewicz, et al., 2004). There is very little research on recovery from concussion in younger, school-aged children (Kirkwood et al. 2006). In a metanalytic review of factors that could possibly influence clinical recovery from sport-related concussion, Iverson et al., (2017) found that the teenage years may be the time period when individuals are most at risk for prolonged concussion recovery.

Thus, it is important to extend research on concussion recovery in adolescence. The period commonly referred to as adolescence describes the transition from childhood to adulthood, which is generally demarcated by the onset of puberty (i.e., approximately age 12) until the legal onset of adulthood (i.e., age 18 in the United States; Jaworska & MacQueen, 2015). This time period is marked by significant changes and developmental challenges. To elaborate, with puberty, adolescents experience changes in gonadal hormones and adrenal hormones which give rise to secondary sex characteristics

(Jaworska & MacQueen, 2015; Rapee et al., 2019). In turn, adolescents must adjust to their changing physical appearance, which increasingly resembles that of an adult (Perry & Pauletti, 2011; Sadler, 2017). Furthermore, the adolescent brain undergoes significant changes to support the development of higher order cognitions, specifically, executive functions (i.e., cognitive regulation, emotional regulation, and behavioral regulation; Jaworska & MacQueen, 2015; Sadler, 2017). For example, grey matter volume begins to decrease in adolescence prior to stabilizing in adulthood, which has been described as synaptic pruning or the removal of unnecessary synapses. White matter volume reaches its peak in late adolescence and early adulthood (Jaworska & MacQueen, 2015). Additionally, sensitivity to rewards also reaches its maximum in adolescence (Jaworska & MacQueen, 2015). Aforementioned brain development is evident in increased adolescent risk-taking behavior relative to other life periods (Jaworska & MacQueen, 2015; Rapee et al., 2019). Increasingly complex social relationships, seeking increased autonomy from caregivers, and planning academic and vocational futures, are all psychosocial hallmarks of the adolescent period (Perry & Pauletti, 2011; Rapee et al., 2019). Overall, adolescence is a period of great change, during which time adolescents face the task of developing a coherent sense of self or self-concept, which incorporates their life experiences as well as social feedback from their environment (Perry & Pauletti, 2011). Considering these factors, it is unsurprising that the adolescent developmental period is associated with stress and emotional reactivity (Jaworska & MacQueen, 2015; Perry & Pauletti, 2011; Rapee et al., 2019). Correspondingly, the occurrence of psychiatric illnesses increases remarkably in adolescence. More specifically, there is a notable increase in the incidence of depression and anxiety disorders in adolescence, with higher rates in females than in males (Rapee et al., 2019; Jaworska & MacQueen, 2015).

Sex and Gender

In recent years, the psychological community and other scientific communities have paid increasing attention to the difference between sex and gender. These interrelated concepts are explained briefly here, before a review of the concussion literature related to each term. The American Psychological Association Dictionary defined the terms of gender and sex in an effort to help psychologists, health service practitioners, researchers, and the public better understand these concepts:

> Sex (n): (1) the traits that distinguish between males and females. Sex refers especially to physical and biological traits, whereas *GENDER* refers especially to social or cultural traits, although the distinction between the two terms is not regularly observed. (2) the physiological and psychological processes related to procreation and erotic pleasure. (American Psychological Association, 2015, pp. 5-6).

From this definition, it is clear that while sex and gender are interrelated concepts, the concepts are distinct. Sex relates to the concepts of maleness and femaleness in a strictly biological and physiological manner, while gender relates to the concepts of masculinity and femininity in a psychological, behavioral, social, and cultural manner (American Psychological Association, 2015, p. 2). In this way, individuals vary in their psychological, affective, and cognitive experiences of congruency between their biological sex and the construal of their gender identity, which is based on environmental and biological factors (American Psychological Association, 2015, p. 4). Cisgender people are those individuals whose sense of gender identity matches the sex the individual had at birth. Some individuals who do not believe their gender identity matches their sex at birth identify their genders differently. Some individuals who believe their gender cannot be described with a gender binary (i.e., male/female) may identify as genderqueer. Still others who feel a sense of incongruency between their sex and gender, but do identify with a gender binary, may identify as transgender (American Psychological Association, 2015).

It is important that research acknowledges the difference between sex and gender and accounts for the influence of both. In 2016, the special issue of the journal, *Archives of Physical Medicine and Rehabilitation*, called "Sex, Gender, and Traumatic Brain Injury: A Commentary," explained the importance of acknowledging sex and gender in research. The articles called attention to the dearth of research using sex-stratified data as well as gender analysis in TBI research (Colantonio, 2016). In research on illnesses and injuries, the need for recognizing both gender and sex is crucial since physiological factors, such as hormones, and environmental influences, such as gender norms, may influence symptom experiences and reporting. Below is a review of concussion research by gender and sex. Authors often use sex and gender interchangeably, which does not acknowledge the important distinctions between the terms. Mollayeva, Mollayeva, and colleagues (2018) have suggested that: "Explicit and consistent consideration of the interrelated constructs of sex and gender in TBI research will produce a better understanding of the different mechanisms that shape the health status trajectory and outcomes of TBI" (p. 711).

Gender. Different gender norms and role expectations may impact the reported prevalence and incidence of TBI. Medical help-seeking after a head injury is influenced by a number of factors that intersect with gender, such as family attitudes and societal attitudes (Mollayeva, Mollayeva, et al., 2018). Furthermore, research indicates that across cultures women are stereotyped to be more emotional than men, and the stereotypes are supported by research on expression rather than experience (Brody & Hall, 2008). This is important to consider in the context of symptom reporting and head injury reporting.

There are few studies that meaningfully incorporate the concept of gender into concussion research. The following studies on concussion used the construct gender. Kroshus and colleagues (2017) examined whether gender would influence concussion reporting among young adult athletes. Results indicated that when compared to their male counterparts, female athletes were more likely to continue to play while symptomatic before reporting a concussion. Similarly, Sullivan and Molcho (2018) explored concussion reporting and intent to report concussion in a group of male and female high school athletes. Regardless of gender, over half of all participants reported that they had played while symptomatic after head injury. When compared to female athletes, male athletes reported they would be less likely to report a concussion as well as more negative outcomes associated with reporting a concussion (Sullivan & Molcho, 2018). In another study with high school athletes, Miyashita and colleagues (2016) used a cross-sectional design to assess the likelihood of reporting a concussion before and after an educational intervention on concussion awareness. Results indicated that females were more likely than males to report a concussion both prior to and after the intervention. Males and females did not differ in their rationales for not reporting a concussion. Males and females tend to differ along gender lines in their concussion reporting behavior.

Sex. In recent years, concussion research has focused on factors that prolong concussion recovery as well as on potential sex influences on concussion recovery outcomes. According to a systematic review by Cancielliere and colleagues (2016), fewer than 10% of studies focused on prognosis after mTBI used sex-stratified data. Similar to all areas of concussion research, however, the majority of these studies focused on the adult population. Studies on humans and animals suggest that females have poorer outcomes than do their male counterparts after brain injury (Broshek et al., 2005).

Metanalytic research findings across age groups suggest that females endure more concussions and have higher levels of concussion-related symptom reporting than do males (Dick, 2009; Brown et al., 2015). Dick (2009) conducted a metanalysis of over 51 studies and found that, compared to males, females had higher incidences of injury and a worse outcome of brain injury. Additionally, females had different baseline and post-concussion outcomes on neuropsychological testing. This suggests that females may be at greater risk for concussions and their prognosis for recovery may be poorer (Dick, 2009). Brown and colleagues (2015) conducted a systematic review and meta-analysis of 21 observational cohort studies with the objective of assessing differences between males and females in baseline pre-season testing and post-concussion testing. Results of baseline testing indicated that females reported symptoms of vision/hearing problems, headache/migraine, difficulty concentrating, energy/sleep disturbances, and emotional disturbances more often than did males (Brown et al., 2015). After incurring an injury, males and females did not differ in symptom reporting, with the exception of one symptom. Females were significantly less likely than males to report the symptom of confusion.

Prospective studies in the adult population have also indicated differences in concussion outcomes by sex. Bazarian and colleagues (2010) assessed the influence of sex on concussion outcomes in a sample of 1,425 mild traumatic brain injury patients after three months post-injury. Females had higher post-concussive symptom scores than males, particularly if females were in their childbearing years. However, sex was not significantly related to days missed from work or normal activities (Bazarian et al., 2010). Ponsford and colleagues (2000) also investigated factors associated with prolonged concussion symptoms in an adult population. After three months post-injury, about one quarter of the participants were still experiencing distress and symptoms. Participants in this group had an increased probability of being a student, being female, having a history of more than one head injury, and having a history of mental health problems (Ponsford et al., 2000).

Although not as extensive as the research is in the adult population, research on youth indicates potential differences in concussion outcomes based on sex. Broshek and colleagues (2005) compared preseason neurocognitive testing results with post-concussion neurocognitive testing results of male and female high school and collegiate athletes who endured sports-related concussions. After concussion, female athletes performed worse on reaction time tasks compared to their baseline pre-season performance and reported more post-concussive symptoms than did males. In general, females tended to experience cognitive impairment as a result of concussion at twice the rate of males. In a prospective study on 296 male and female high school and college athletes, Covassin and colleagues (2012) identified differences in post-concussive symptoms and cognitions in athletes at baseline and then at 2, 7, and 14-day post-concussion intervals. All female participants reported more symptoms and performed more poorly on visual memory tasks than did their male counterparts (Covassin et al., 2012).

There are few studies on sex differences in concussion outcomes using strictly pediatric populations. In a recent study, Sandel, Schatz, and colleagues (2017) explored sex-based differences in post-concussive neurocognitive functioning and symptom reporting outcomes in 224 concussed adolescent male and female lacrosse players compared with a group of soccer players aged 13 to 17 years. Regardless of sport, female athletes demonstrated greater neurocognitive deficits and more symptoms after a concussive injury when compared to males. Over twice as many females earned performance scores that were consistent with prolonged recovery as compared to males (Sandel, Schatz, et al., 2017). Iverson and colleagues (2017) conducted a systematic review of 7616 articles for factors related to clinical recovery from concussion, which was operationalized as a return to normal activities after injury. Regarding sex differences, girls in their teenage years were found to be at the greatest risk for prolonged recovery from concussion (Iverson et al., 2017).

Somatization

According to Gupta Karkhanis and Winsler (2016) somatization can be defined as, "…the propensity to experience and report psychological and/or emotional suffering through physical symptoms that cannot be explained by known medical causes" (p. 9). Examples of somatic complaints may be nausea or headaches without medical cause (Ram, 2015). Somatic complaints may be related to difficulty in voicing emotional distress, which is not uncommon in the pediatric population (Gupta Karkhanis & Winsler, 2016). Factors related to somatization include: a family history of health problems, family reinforcement of "sick" behavior, personality, psychological factors, gender, and culture (Gupta Karkhanis & Winsler, 2016). Somatic symptoms are often reported by youth who experience difficulties in functioning and who have difficulties in expressing and identifying emotions.

In a sample of 356 school-aged youth and their mothers, Cerutti et al. (2017) found a strong positive correlation between children's and mothers' scores on a measure of somatization. Functional impairment also correlated with somatization. In addition to a significant relationship between somatic symptoms and criteria for alexithymia (i.e., inability or difficulty identifying emotions in oneself), somatic symptoms mediated the relationship between problems in identifying feelings and functional impairment (Cerutti et al., 2017). Youth with somatic complaints may be at increased risk for emotional disorders during childhood. Shanahan and colleagues (2015) conducted a 10-year prospective-longitudinal study with a community sample of almost 1,500 participants aged 9 to 16 years old to assess whether a history of frequent somatic complaints in childhood and adolescence could predict emotional disturbances in adulthood after accounting for childhood psychiatric and physical health status and psychosocial adversity. Results of the study indicated that ongoing somatic complaints in youth were related to emotional disorders in adulthood (Shanahan et al., 2015). Shanahan and colleagues (2015) recommended prevention efforts and interventions for somatic complaints in order to decrease this risk factor.

There have been few studies examining somatization in concussion symptoms. In a prospective cohort study with a sample of 10 to 18-year-olds diagnosed with concussion, Root et al. (2016) assessed participants at baseline, 2 weeks, and 4 weeks on post-concussive symptoms and somatization. Higher pre-injury concussion symptom scores were related to higher concussion symptom scores across time. Additionally, females with the highest scores in somatization had the most prolonged post-concussive symptoms at the 4 weeks after baseline assessment. Root et al. (2016) suggested that somatization may relate to sex differences in recovery and that assessments at the time of concussion may be useful to formulate treatment trajectory. Howell et al. (2016) also found a significant relationship between initial reporting of somatic symptom severity and prolonged concussion symptom duration in adolescents aged 13 to 18 years old. In the Howell et al. (2016) study, there was not a significant relation between initial reporting of somatic symptom severity and prolonged duration of PCS in children aged 8 to 12 years old. However, the sample sizes may have influenced these results. The adolescent sample had 250 participants while the child sample had only 68 participants. Grubenhoff and colleagues (2016) conducted a longitudinal cohort study to determine the psychological factors associated with prolonged recovery from concussion in the pediatric population. After one month, approximately one fifth of the participants were still experiencing delayed symptom improvement or recovery. Somatization was related to delayed symptom resolution as approximately 34% of children with delayed symptom resolution had abnormal somatization scores (Grubenhoff et al., 2016).

Summary

Although most research on concussion has utilized adult and collegiate populations, there has been recent progress in research on pediatric concussion recovery. More research on concussion outcomes is necessary for the pediatric population. In the adult population, mood disturbance has been directly related to adverse outcomes following concussion as well as to prolonged recovery from concussion (Mainwaring et al., 2012), yet few studies have explored mood disturbance in pediatric populations. Additionally, research on concussion and age-related outcomes reveals that different age-groups recover from concussive injuries at different rates, with adolescents at particular risk for prolonged recovery (Iverson et al., 2017; Nelson et al., 2016; Zuckerman et al., 2012). While sex and gender differences in concussion recovery have been revealed (Brown et al., 2015; Dick, 2009; Kroshus et al., 2017; Miyashita et al., 2016), research to replicate these findings with pediatric samples is needed. Finally, somatization appears to impact symptom reporting in those who endure concussions (Grubenhoff et al., 2016; Howell et al. 2016; Root et al. 2016). More information on concussion outcomes in the pediatric population could help to guide early intervention efforts and improve overall concussion care.

The Present Study

The purpose of this study was to explore possible predictors of concussion recovery in youth aged 12 to 17 years old who presented for neuropsychological evaluation after head injury. The primary aims of this study were to examine how symptoms of mood disturbance (i.e., anxiety, depression, anger), somatization, age, and gender relate to the odds of concussion recovery in youth.

Hypotheses:

1) Symptoms of mood disturbance will predict concussion recovery in the following ways:

a) Anxiety symptoms will predict decreased odds of concussion recovery.

b) Depression symptoms will predict decreased odds of concussion recovery.

c) Anger symptoms will predict decreased odds of concussion recovery.

2) Somatization symptoms will predict decreased odds of concussion recovery.

3) Female gender (in adolescents ages 12 to 17) will predict decreased odds of concussion recovery.

4) Mood disturbance (i.e., depression, anxiety, anger), somatization symptoms, age, and gender will be related to decreased odds of concussion recovery.

CHAPTER 3

METHODOLOGY

Participants

Prior to data collection, all procedures in this study were approved by the Phoenix Children's Hospital (PCH) Institutional Review Board and the Arizona State University (ASU) Institutional Review Board. The original data gathering met all the data gathering requirements of PCH, ASU, and the Health Insurance Portability and Accountability Act (HIPPA) of 1996. Information from the medical records of males and females aged 7 to 17 years old who were seen for neuropsychological evaluation of concussion by the Division Chief of Neuropsychology in the Phoenix Children's Hospital (PCH) Concussion Clinic between November 2015 and November 2018 was reviewed for inclusion in the study. In available records, 262 children and adolescents were identified who were seen for concussion evaluation. Further review indicated 140 records included key study measures of mood disturbance (i.e., *Beck Youth Inventories, Second Edition*; specified below in the Variables and Measures section), while 48 did not. The remaining 74 records were not included due to being concussion re-evaluations of patients already identified for inclusion or due to classifications more severe than mTBI. Of the 140 records identified for inclusion in the study, 32 included children aged 8 to 11. Due to the small sample size of younger children, only the 108 adolescents aged 12 to 17 were included in the study. Importantly, medical records contained incomplete information on race, so this demographic was not reported. As only 3 patients were identified as transgender or genderqueer in medical records, only cisgender males and females were included in the study.

The final sample size of 108 was more than adequate to assess mean comparisons. According to recommendations by Hosmer and colleagues (2013), a minimum of 15 cases is required per independent variable for adequate power in a logistic regression; thus, given 6 independent variables in the study, the necessary sample size is 90, which suggests adequate power for the current sample size of 108. The participant mean age was 15 years old (*SD* = 1.29, Range = 5). Participant gender demographics are as follows: females (*n* = 57) and males (*n* = 51). The mean time from concussion was 88.71 days (SD = 36.60, Range = 152). All but one patient was seen 4 weeks after concussion, which suggests prolonged recovery for nearly all adolescent patients included (Barlow, 2016; Ledoux et al., 2019).

Variables and Measures

Demographics and Characteristics. General demographic information was collected from neuropsychological medical records, including gender and age. Additional characteristics collected included time since most recent concussion, number of lifetime concussions, and nature of most recent concussion.

Concussion Recovery. Concussion recovery was determined by one neuropsychologist using neuropsychological assessments and a diagnostic interview. Depending on the presence of cognitive deficits, the neuropsychologist determined whether symptoms were consistent with recovery. It follows that concussion recovery is a dichotomous variable in the study (i.e., recovered or not recovered). The primary neuropsychological assessments used for the determination included the *Wechsler Abbreviated Scale of Intelligence, Second Edition* (*WASI-II*; Wechsler, 2011) and the *Wechsler Intelligence Scale for Children, Fifth Edition* (*WISC-V*; Wechsler, 2014). For adolescents over age 16 years old, the *Wechsler Adult Intelligence Scale, Fourth Edition* (*WAIS-IV*; Wechsler, 2008) was used.

Anxiety, Depression, and Anger. Anxiety, depression, and anger were measured with T-scores from subscales of the *Beck Youth Inventories, Second Edition* (*BYI-2*; Beck, 2005). The inventory is suitable for children aged 7 to 18 years old. Each symptom subscale is composed of 20 questions with a Likert response format ranging from 0 to 3 to denote symptom frequency (i.e., "0 = never," "1 = sometimes," "2 = often," "3 = very often"). The Depression Inventory questions are based on negative thoughts, feelings of guilt and sadness, and sleep issues. For example, one item is "I have trouble sleeping." The Anxiety Inventory questions are focused on concerns and apprehension regarding school, the future, reactions from others, losing control, and physiological anxiety symptoms; "My hands shake." The Anger Inventory questions are centered on feelings of hatred and anger as well as thoughts of unjust or unfair treatment. For example, one item is "I get mad and stay mad." Each inventory takes about 5 minutes to complete. Scores are summed and converted to T-Scores. According to the manual, internal consistency for each scale ranges from .86 to .96, and the test-retest reliabilities for each scale range from .74 to .93 (Beck, 2005). The anxiety, depression, and anger scales have shown adequate convergent validity with scales measuring related constructs (Beck, 2005).

Somatization. Parents assessed all observed somatization symptoms in their child. Somatization was measured with the somatization subscale of the *Behavior Assessment System for Children, Third Edition* (*BASC-3*; Reynolds & Kamphaus, 2015). The *BASC-3* is an inventory that assesses various domains of adaptive and problem behaviors in the community and home setting. An example of an item from the somatization subscale is: "Complains of physical problems." The inventory is suitable for children and emerging adults aged 2 to 25 years old; however, there are different scales depending on age group. Parents completed the adolescent form for children aged 12 to 21. The questionnaire takes about 15 minutes to complete. While the *BASC-3* has numerous scales, the T-score from the somatization scale was the primary focus of this study. According to the manual, internal consistency coefficients for each subscale range from .80 to .90, which suggests that items within each scale are related to each other and the construct being measured (Reynolds & Kamphaus, 2015).

Procedures

Adolescents seen for neuropsychological evaluation of concussion in the PCH Concussion Clinic were administered a variety of neuropsychological assessments and questionnaires. Patient's parents also completed questionnaires, rating forms and inventories. The data for this study were extracted from neuropsychological reports, which included patient test and rating scale scores completed as part of the standard neuropsychological screening for concussion at PCH, as well as demographic information from medical records. Importantly, neuropsychological assessments in conjunction with a clinical interview determined whether patients presented with cognitive deficits consistent with prolonged concussion recovery. Retrospective chart review was completed for male and female patients ages 7 to 17 years old who were seen or being seen for neuropsychological evaluation of concussion in the PCH Concussion Clinic between November 2015 and November 2018. Analysis of three years of patient data was completed to ensure an adequate sample size with sufficient diversity in age and gender. Questionnaire scores, concussion evaluation result (i.e., recovered/not recovered), and demographic information were entered and stored in a Microsoft Excel version 15.18 spreadsheet prior to analysis. All statistical analyses were performed utilizing SPSS version 27.

Data Analyses Plan

As the dependent variable, concussion recovery, is a nominal variable with two options, recovered and not recovered, logistic regression was used in analyses. In order to perform logistic regression, the data must meet the methodological assumptions of logistic regression (Hosmer et al., 2013). A Box-Tidwell procedure was completed to assess for a linear relationship between the continuous independent variables and the logit transformation of the dependent variable. Predictor variable VIF values were assessed to determine multicollinearity and data was assessed for significant outliers using standardized residuals. Preliminary evaluation of group differences between adolescents recovered and not recovered from concussion were completed with respect to gender, anxiety, depression, anger, and somatization. Binary logistic regression was used to assess hypotheses 1, 2, and 3, which assess simple bivariate odds between concussion recovery and anxiety, depression, anger, somatization, and gender, respectively. Multiple logistic regression was used to assess hypothesis 4, which assesses the impact of depression, anxiety, anger, somatization, gender, and age on the odds of concussion recovery.

CHAPTER 4

RESULTS

Preliminary Evaluation of Group Differences

A test of two proportions was completed to explore differences in recovery based on gender. After initial neuropsychological evaluation for concussion, 30 females (52.6%) displayed persistent concussion symptoms compared to 16 males (31.4%), a statistically significant difference in proportions of .212, $p < .05$.

Mean differences in mood and somatization symptom burden were assessed between those who had recovered (n = 62) and those who had not recovered (n = 46) from concussion at evaluation (see Table 1). Somatization, anxiety, depression, and anger did not demonstrate outliers and were normally distributed per the Shapiro-Wilk's test. An independent-samples t-test was run to determine differences in somatization between those who had recovered from concussion and those who had not. There was homogeneity of variances, as assessed by Levene's test for equality of variances (p = .151). Somatization symptoms were higher in those who had not recovered from concussion (M = 58.89, SD = 11.89) than in those who had recovered (M = 50.40, SD = 8.30), indicating a statistically significant difference with large effect size, M = 8.48, SE = 1.94, $t(106) = 4.367$, p = .001, *Cohen's d* = .85.

Welch's t-tests were run to determine differences between those who had recovered (n = 62) and those who had not recovered (n = 46) with respect to the remaining predictor variables due to the assumption of homogeneity of variances being violated for all (i.e., Levene's test for equality of variances $p < .05$). Group differences in anxiety symptoms were found, M = 6.353, SE = 2.381, $t(74.08) = 2.668$, p = 009. Anxiety symptoms were higher in those who had not recovered from concussion (*M* = 56.80, *SD* = 13.97) as compared to those who had recovered (*M* = 50.45, *SD* = 9.39). Depression symptoms also differed, *M* = 7.33, *SE* = 2.06, *t*(67.69) = 3.554, *p* = 001. Depression was greater in those who had not recovered from concussion (*M* = 54.15, *SD* = 12.48) as compared to those who had recovered (*M* = 46.82 *SD* = 7.327). Anger symptoms differed between groups, *M* = 4.88, *SE* = 2.215, *t*(65.04) = 2.297, *p* = .025. Anger symptoms were higher in those who had not recovered from concussion (M = 50.48, SD = 13.028) as compared to those who had recovered (M = 45.60, SD = 7.164).

Table 1

Sample Demographics and Characteristics

Characteristic	Total n (%)	Recovered n (%)	Not Recovered n (%)
Age (Years)			
12-13	16 (14.81)	10 (16.13)	6 (13.04)
14-15	52 (48.15)	23 (37.10)	29 (63.04)
16-17	40 (37.04)	29 (46.77)	11 (23.91)
Gender			
Females	57 (52.78)	27 (43.54)	30 (65.21)
Males	51 (47.22)	35 (56.45)	16 (34.78)
Number of Prior Concussions			
Current Concussion	74 (68.5)	41 (66.1)	33 (71.7)
2 Concussions	18 (16.7)	14 (22.6)	4 (8.7)
3 Concussions	13 (12)	7 (11.3)	6 (13.0)
4 Concussions	3 (2.8)	-	3 (6.5)
Nature of Concussion			
Sports Related	39 (36.1)	27 (43.5)	12 (26.1)
Recreation	14 (13)	8 (12.9)	6 (13.0)
Accidental Injury	49 (45.4)	24 (38.7)	25 (54.3)
Assault	6 (5.6)	3 (4.8)	3 (6.5)
Total	108	62	46

Hypothesis Testing

Hypothesis 1a: Anxiety symptoms will predict decreased odds of concussion recovery. Binary logistic regression of anxiety symptoms on concussion recovery was statistically significant (unstandardized B = -.048, SE = .018, Wald = 7.038, p =.008., *Exp(B)* = .953). The estimated odds ratio suggests for every one unit increase in anxiety symptoms the odds of recovery from concussion at initial evaluation are reduced by a factor of .953, or 4.7%.

Hypothesis 1b: Depression symptoms will predict decreased odds of concussion recovery. Binary logistic regression of depression symptoms on concussion recovery was statistically significant (unstandardized B = -.076, SE = .022, Wald = 11.493, p <.001, (*Exp(B)* = .927). The estimated odds ratio suggests for every one unit increase in depression symptoms the odds of recovery from concussion at initial evaluation are reduced by a factor of .927 or 7.3%.

Hypothesis 1c: Anger symptoms will predict decreased odds of concussion recovery. Binary logistic regression of anger symptoms on concussion recovery was statistically significant (unstandardized B = -.050, SE = .021, Wald = 5.466, p = .009, *Exp(B)* = .951). The estimated odds ratio suggests for every one unit increase in anger symptoms the odds of recovery from concussion at initial evaluation are reduced by a factor of 1.05 or 4.9%.

Hypothesis 2: Somatization symptoms will predict decreased odds of concussion recovery. Binary logistic regression of somatization symptoms on concussion recovery was statistically significant (unstandardized B = -.088, SE = .024, Wald = 13.501, p <001, *Exp(B)* = .916). The estimated odds ratio suggests for every one unit increase in somatization symptoms the odds of recovery from concussion at initial evaluation are reduced by a factor of 1.09 or 8.4%.

Hypothesis 3: Female gender (in adolescents aged 12 to 17) will predict decreased odds of concussion recovery. Binary logistic regression of gender on concussion recovery was statistically significant (unstandardized *B* = -.88*,* SE = .402, Wald = 4.886, *p* = .027, *Exp(B)* = .411). For females the estimated odds ratio suggests their odds of recovery from concussion are less than those for males by a factor of .411 or 58.9%.

Hypothesis 4: Mood disturbance (i.e., depression, anxiety, anger), somatization symptoms, age, and gender will be related to decreased odds of concussion recovery. A binomial logistic regression was performed to ascertain the impact of age, gender, anxiety, depression, anger, and somatization on the likelihood of recovery from concussion. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. A Bonferroni correction was applied using all terms in the model resulting in statistical significance being accepted when $p < .004$ (Tabachnick & Fidell, 2014). Based on this assessment, all continuous independent variables were found to be linearly related to the logit of the dependent variable. Prior to performing logistic regression analyses, collinearity was assessed using variance inflation factors (VIF) and zero-order correlations amongst the continuous predictor variables. All continuous variables had VIFs below 5 and zero-order correlations below .8 (see Table 2), which indicates acceptable collinearity per recommendations of Midi and colleagues (2010). Outliers were assessed utilizing standardized residuals, and all cases were maintained in the model.

Table 2

Summary of Intercorrelations for Scores on Age, Anxiety, Depression, Anger, and Somatization

	1	*2*	3	*4*	*5*
1. Age	-	.444	.396	.483	-.040
2. Anxiety	-.005	-	.757	.616	.221
3. Depression	-.046	.770	-	.769	.335
4. Anger	.174	.743	.674	-	.253
5. Somatization	-.423	.291	.497	.261	-

Note: Intercorrelations for males are presented above the diagonal, and intercorrelations for females are presented below the diagonal.

A backward variable selection procedure was performed with all six predictor variables to arrive at the model with the best fit. The initial logistic regression model was significant $\chi 2(6) = 26.834$, $p < .00$. The Hosmer-Lemeshow goodness-of-fit test was not significant ($p > 0.05$) indicating a correctly specified model. The model explained 29.6% (Nagelkerke R Square) of the variance in concussion recovery and correctly classified 68.5% of cases. Age, gender, anxiety, depression, and anger did not meet inclusion criteria ($p < .10$) for the final model and were not significant ($p > 0.05$); however, somatization was significant ($p < 0.05$) and was included (as shown in Table 3).

Table 3

Initial Logistic Regression Model Predicting Odds of Recovery from Concussion based on Age, Gender, Anxiety, Depression, Anger, and Somatization

	B	*SE*	Wald	*df*	*p*	Odds Ratio	95% CI for Odds Ratio	
							Lower	Upper
Age	-.081	.200	.163	1	.686	.922	.623	1.365
Gender	-.830	.472	3.089	1	.079	.436	.173	1.100
Anxiety	.017	.038	.198	1	.656	1.017	.944	1.096
Depression	-.114	.062	3.415	1	.065	.892	.791	1.007
Anger	.050	.054	.828	1	.363	1.051	.944	1.169
Somatization	-.067	.027	6.037	1	.014	.935	.886	.986

Note: Gender is for females compared to males, with males acting as the reference group.

The final logistic regression model was statistically significant, $\chi2(2) = 23.14$, $p <$ .00, with the Hosmer-Lemeshow goodness-of-fit test not significant ($p > 0.05$), indicating a correctly specified final model. The model explained 25.9% (Nagelkerke R Square) of the variance in concussion recovery and correctly classified 70.4% of cases. Of the original 6 predictor variables, age, gender, anxiety, and anger did not meet inclusion criteria ($p < .10$) for the final model and were not significant ($p > 0.05$), while depression and somatization were significant ($p < 0.05$) and contributed to the model (as shown in Table 4). For each unit increase in depression symptoms, the odds of concussion recovery decline by a factor of .949 or 5.1%. Similarly, for each unit increase in somatization symptoms, the odds of concussion recovery decline by a factor of .933 or 6.7%. Said differently, as symptoms of depression or somatization increase, the likelihood of recovery at time of initial evaluation declines.

Table 4

Final Logistic Regression Model Predicting Odds of Recovery from Concussion based on Depression and Somatization

	B	*SE*	Wald	*df*	*p*	Odds Ratio	95% CI for Odds Ratio	
							Lower	Upper
Depression	-.053	.024	4.929	1	.026	.949	.905	.994
Somatization	-.073	.026	8.075	1	.004	.930	.884	.978

Note: Final model derived from backward selection based on removal criteria of $p < .10$.

CHAPTER 5

DISCUSSION

Concussion is a mild form of TBI (Lezak et al., 2012). While most youth recover from concussion symptoms within 2 to 4 weeks (Ledoux et al., 2019), some research suggests over a quarter of concussed children and adolescents endure prolonged symptoms, which sometimes includes mood disturbance sequelae for up to three months or longer duration (Barlow, 2016; Brent & Max, 2017; Ledoux et al., 2019). Few studies have assessed mood disturbance associated with concussion in pediatric populations. The current study examined how symptoms of mood disturbance (i.e., anxiety, depression, anger) and somatization relate to the odds of concussion recovery in male and female youth 12 to 17 years of age, who presented for neuropsychological evaluation after head injury. Overall, study findings yielded some evidence of increased symptoms of mood disturbance and somatization in those with persistent symptoms of concussion relative to those who recovered. Furthermore, findings also help to uncover factors which may reduce the odds of recovery from concussion or prolong concussion recovery in adolescents. A review of study findings follows.

Bivariate analyses of mood disturbance predictors amongst those who recovered from concussion and those who had not revealed significant group differences in symptom burden. Specifically, the group of adolescents who displayed persistent symptoms of concussion at initial concussion evaluation also displayed significantly higher symptom burden regarding depression, anger, and anxiety as compared to adolescents who were deemed recovered at initial concussion evaluation. Furthermore, hypothesized bivariate logistic regressions of mood disturbance predictors on concussion recovery (i.e., hypothesis 1) indicated as symptoms of anger, anxiety, or depression symptoms increase a modest decline in the odds of recovery, or remission of concussion symptoms, at initial evaluation may be expected. These findings are consistent with a small yet increasing number of studies that have sought to explore mood disturbance in the pediatric population following concussion. To elaborate, in the acute phase of injury and in the first few months directly following concussions, research has indicated youth are at risk for socio-emotional stress and mood changes (Ellis et al., 2015; Massagli et al., 2004; Max et al., 2013; Sariaslan et al. 2016), increased depression symptoms (Emery et al., 2016; Kontos et al.,2012), increased anxiety symptoms (Bloom et al., 2004; Iverson, 2006; Kneightley et al., 2014) and increased anger and irritability (Hunt, 2015; Provvidenza et al., 2013). Additional research suggests even one concussion may result in future anxiety disorders and depression disorders months and years after injury (Chrisman & Richardson, 2014; Grubenhoff et al., 2016; Ellis et al., 2015; Massagli et al., 2004; Max et al., 2013). Findings and prior research highlight the potential importance of screening for mood disturbance in pediatric patients following concussion in all phases of recovery.

Although a small, yet growing number of studies, have explored mood disturbance in the pediatric population recovering from concussion, less attention has been paid to the presence of somatization in this population. In the current study, bivariate analysis, using an independent-samples t-test, revealed adolescents with persistent symptoms of concussion at initial evaluation displayed significantly more symptoms of somatization (i.e., the tendency to be overly sensitive to, to experience, or to complain about relatively minor physical problems and discomforts) than adolescents who recovered. This finding was associated with a particularly large effect size. The hypothesized bivariate logistic regression of somatization on concussion recovery (i.e., hypothesis 2) indicated as symptoms of somatization increase, the odds of recovery at evaluation are slightly reduced. Study findings are consistent with and contribute to extent research suggesting a segment of pediatric patients with persistent symptoms of concussion display higher somatization symptoms as compared to those who recover (Grubenhoff et al., 2016; Root et al. 2016). To illustrate, in a longitudinal cohort study, Grubenhoff and colleagues (2016) found that somatization was related to delayed symptom resolution in over one-third of children with delayed symptom resolution (Grubenhoff et al., 2016). Furthermore Root et al. (2016) found that higher pre-injury somatization symptom scores were related to higher concussion symptom and somatization scores after initial injury.

When differences in recovery at time of evaluation were analyzed based on gender, significant group differences emerged. Results of an analysis of two proportions, or chi-square, revealed that female adolescents in the sample were more likely to display persistent concussion symptoms than were male adolescents. The hypothesized bivariate logistic regression of gender on concussion recovery (i.e., hypothesis 3) indicated the odds of female adolescent recovery from concussion at evaluation were almost 60% lower than those for male adolescents. A few studies have also suggested that female adolescents tend to have increased risk for greater post-concussion symptoms and more prolonged recovery times after concussions (Crowe et al., 2016; Iverson et al., 2017; Nelson et al., 2016; Thomas et al., 2018; Zemek et al., 2016; Zuckerman et al., 2012). It is also important to contextualize the current findings within adolescent gender development for cisgender individuals. During adolescence, females typically are socialized to self-disclose about their emotions, whereas males are typically socialized to inhibit emotional expression (Perry & Pauletti, 2011). This is consistent with research that suggests medical help-seeking after a head injury is influenced by a number of factors that intersect with gender, such as family attitudes and societal attitudes (Mollayeva, Mollayeva, et al., 2018). Furthermore, a few studies with high school athletes have demonstrated females are more likely to report initial symptoms of concussion after injury (Miyashita et al., 2016; Sullivan & Molcho, 2018), a pattern which may extend to symptom reporting at initial neuropsychological evaluation. Nevertheless, there are physiological differences on the basis of sex between males and females which may also contribute to recovery. It is likely that gender differences in concussion recovery have multifactorial etiologies.

Previous research findings and current study findings highlight the existence and significance of symptoms of mood disturbance and somatization in youth recovering from concussion. Furthermore, adolescent age and gender have been significant predictors of prolonged recovery from concussion. Thus, a model exploring the odds of concussion recovery based on these factors was explored (i.e., hypothesis 4). The hypothesized multivariable logistic regression model of mood disturbance predictors, somatization, gender, and age was significant and explained over 25% of the variance in concussion recovery at initial evaluation. However, after a backward variable selection procedure, only depression and somatization symptoms were significant in the final model and accounted for a modest decline in the odds of recovery from concussion at initial evaluation. Given the significance of all bivariate logistic regressions and prior research, it was unexpected that anger, anxiety, and gender did not significantly contribute to model fit, and thus the odds of concussion recovery. Practically, the difference in results between the bivariate logistic regressions and the multivariable model might be explained by reduced power in the multivariable model with the addition of more predictors (i.e., 6 predicter variables in multivariable model versus 1 predicter variable in bivariate logistic regressions).

Strengths and Limitations of the Current Study

A major strength of this study is the use of a comprehensive neuropsychological evaluation by an experienced neuropsychologist to determine adolescent recovery from concussion along with data from well researched measures on pediatric mood and behavior as variables for mood disturbance and somatization (i.e., *BASC-3* and *BYI-2*). Study findings extend the minimal extent research on pediatric mood disturbance following concussion, particularly in relation to persistent symptoms of concussion. Furthermore, only a handful of studies have analyzed the impact of somatization on concussion recovery in the pediatric population; thus, the current study contributes to this developing area of research. Nevertheless, this study has several limitations. First, this study utilized a retrospective design and collected data not initially meant to be utilized for research. Thus, a selection bias may exist since data collection was guided by the inclusion of cases that included specific variables. To elaborate, only patients who were administered the *Beck Youth Inventories, Second Edition* (*BYI-2*; Beck, 2005) and whose parents were administered the *Behavior Assessment System for Children, Third Edition, Parent Report* (*BASC-3*; Reynolds & Kamphaus, 2015) were included in the study. While these patients reflect the majority of initial concussion evaluation records reviewed, some patients were not included based on these measures missing from their records. Additionally, amongst the patients included in the study, the time since initial concussion varied greatly, from just under 4 weeks, to 172 days. There may be significant differences in characteristics between patients seen within different time frames after concussion (i.e., within 1 month, within 2 months, etc.); however, the sample size of the current study did not support such analyses. Relatedly, the sample size of 108 patients met the minimum required sample size for a multivariable logistic regression with 6 predictors, per recommendations of Hosmer and colleagues (2013). However, it is likely that a larger sample size would have allowed for a more robust analysis of the multivariable model given the significance of the bivariate logistic regressions. When study limitations are considered in the context of extent research, which suggests a proportion of adolescents experience mood disturbance and somatization following concussion, study findings should be cautiously generalized to the population of adolescents recovering from concussion.

Implications for Future Research

Future research could address some of the limitations in this study. The current study lays groundwork for future prospective studies on concussion recovery, mood disturbance, somatization, and relevant covariates. Specifically, it would be particularly useful to measure mood and somatization symptoms with standardized measures at several time points in a pediatric sample along with continued symptoms of concussion after initial evaluation or persistent symptoms. Furthermore, a mixed method design would allow for the use of standardized measures of mood and somatization symptoms along with qualitative measures (i.e., adolescent report of mood and somatization symptoms during clinical interview). Researchers who replicate and extend these findings using qualitative data from clinical interviews in conjunction with standardized ratings could make important contributions by uncovering additional factors related to mood disturbance or adjustment in youth recovering from concussion. Finally, given parent reports often provide additional context to adolescent self-report, a study utilizing both parent and adolescent measures of variables within a structural equational model may yield meaningful findings regarding latent variables influencing mood disturbance and concussion recovery.

Implications for Practice

The current study has significant implications for practice. This study and a growing number of studies using both experimental and qualitative designs make clear the relationship between concussion recovery, particularly persistent symptoms, and mood disturbance. Furthermore, this study and a small number of other studies suggest high somatization in pediatric patients with persistent symptoms of concussion. Current study results add to the growing number of studies that suggest female adolescents are more likely to display persistent symptoms of concussion. It is clear that medical providers should be aware that mood disturbance following concussion may prolong recovery. Some recommendations for practice based in the literature follow.

In acute care settings, such as emergency rooms, where adolescents often present following head injury, families should be educated regarding the normal course of concussion recovery, as well as the potential for prolonged recovery in some adolescents. The Center for Disease Control and Prevention offers comprehensive coverage on this issue in their Heads Up awareness program with resources available online ("Heads Up", 2021). Importantly, medical professionals in acute care settings may have the first opportunity to educate families on the potential for changes in mood, affect, and behavior following concussion and to inform families on how to seek mental healthcare if symptoms become significant and impact important life areas.

Youth often follow with pediatricians or neurologists after concussion in the acute and subacute phases of injury (McGrath & Eloi, 2019). That being said, these providers should screen for symptoms of mood disturbance in patients they are following for treatment of concussion using a brief interview and brief standardized measures. Appropriate referrals to mental health providers may be issued as indicated by symptoms. Some examples of brief and free mood screeners medical providers could utilize include, the *Mood and Feelings Questionnaire* (Wood et al., 1995) and the *Screen for Anxiety and Related Disorders* (*SCARED*; Birmaher et al., 1997), Additionally, while the concussion itself may cause changes in mood, in both acute care and primary care settings, medical practitioners should be mindful of the relationship between the nature of the injury and possible psychological distress (Goldstein, 2019; McGrath & Eloi, 2019). For instance, adolescents who sustained injuries through a traumatic event, such as a motor vehicle collision, or an assault, may be at heightened risk for psychological distress associated with potential trauma, and therefore at risk for prolonged recovery.

In reference to prolonged concussion recovery, multidisciplinary care is often most efficacious with a pediatrician or neurologist providing care along with a psychologist or a neuropsychologist (Goldstein, 2019; McGrath & Eloi, 2019). Moreover, many children's hospitals have multidisciplinary concussion clinics to optimize care for patients following concussion. Given research findings, it may be best practice for treating physicians to consult neuropsychologists and psychologists when there is concern for prolonged symptom duration in the context psychological distress or somatization.

As neuropsychologists have expert knowledge of both cognitive and psychological functioning, neuropsychological evaluation of patients with prolonged concussion recovery is best practice (McGrath & Eloi, 2019). When prolonged recovery is of concern, a relatively brief, yet comprehensive, neuropsychological battery is indicated. McGrath and colleagues (2019) suggest the inclusion of an intellectual measure with measures of attention/concentration, verbal and language abilities, visuospatial abilities, memory and learning, processing speed, executive function, fine motor speed and dexterity, and academic achievement, along with measures of mood and behavior. Relatedly, even in relatively brief neuropsychological evaluations following concussion, standardized measures of mood, which evaluate depression, anxiety, and other symptoms of mood disturbance should be administered. If mood disturbance or somatization is identified, neuropsychologists are in a unique position to provide feedback on the impact of mood disturbance or somatization on recovery along with brief psychoeducation on treatment options and referrals to psychologists for outpatient therapy and psychiatrists for medication. Furthermore, neuropsychologists may also recommend academic accommodations.

Relatedly, psychologists may intervene to determine if ongoing somatization, or mood disturbance are driving prolonged recovery, and provide intervention (Goldstein, 2019). At present, limited research exists on psychotherapeutic intervention with adolescents with persistent symptoms of concussion and mood disturbance. In the adult population with persistent symptoms of concussion, psychoeducation on concussion recovery, brief interventions on relaxation (e.g., diaphragmatic breathing, guided imagery), and mindfulness (i.e., focusing on the present moment with acceptance), as well as short-term Cognitive Behavioral Therapy (CBT; psychotherapy focused on problem-solving and removing errors in thinking) have demonstrated effectiveness in treating mood symptoms and reducing length of recovery (Broshek et al., 2015). Goldstein (2019) has proposed psychologists utilize similar interventions with the pediatric population to improve mood and prolonged concussive symptomology. Specifically, Goldstein (2019) recommends short-term CBT and ongoing psychoeducation for the families of patients with prolonged recovery and mood symptoms. A strong foundation of research supports the effectiveness of CBT as a first-line treatment of irritability (Roy & Comer, 2020), anxiety (Higa-McMillan et al., 2016), and depression (Weersing et al., 2017) in adolescents. Furthermore, a few recent studies on active rehabilitation (i.e., active approach to recovery versus standard care) suggest improved mood and quality of life for children and adolescents who received active rehabilitation intervention, with core elements of light physical activity, psychoeducation on recovery, and stress management techniques (Gagnon et al. 2016; Gauvin-Lepage et al., 2020). These findings suggest behavioral lifestyle changes along with psychoeducation as well as brief cognitive and behavioral interventions may be effective in treating mood disturbance in adolescents with prolonged recovery from concussion.

Conclusion

This study adds to the literature on pediatric concussion recovery and mood disturbance. Overall, study findings yielded some evidence of increased symptoms of mood disturbance and somatization in those with persistent symptoms of concussion relative to those who recovered. Furthermore, results indicate female adolescents in the sample were more likely to display persistent concussion symptoms than were male adolescents. Additionally, findings also help to uncover factors which may reduce the odds of recovery from concussion or prolong concussion recovery in adolescents. Symptoms of mood disturbance (i.e., anger, depression, and anxiety), somatization, and gender each resulted in a modest decline in the odds of recovery, or remission of concussion symptoms. Unexpectedly, in a multivariable model predicting concussion recovery based on symptoms of mood disturbance, somatization, gender, and age, only depression and somatization resulted in a significant decline in the odds of recovery.

These findings are limited based on the retrospective design and associated selection bias (i.e., only cases with pre-specified variables were included). The study sample size met minimum requirements for a logistic regression, although a larger sample size may have allowed for a more robust analysis of the multivariable model. Future researchers may address these limitations and further research in this area by using prospective study designs with measures of mood disturbance and somatization administered at multiple time points, mixed method designs incorporating standardized measures of mood and somatization as well as qualitative interview data, and structural equation modeling to discover latent variables.

In reference to clinical practice, study findings suggest that mood disturbance and somatization may be important to monitor across concussion recovery. It follows that it may be best practice to include neuropsychologists and psychologists in the care of adolescents presenting with prolonged concussion recovery in the context of mood disturbance and somatization. In conclusion, the results of this study further current knowledge of pediatric concussion recovery and have important implications for the treatment of prolonged concussion recovery in adolescents.

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