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A Primer on Persistent Postconcussion Symptoms

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ABSTRACT: The existence of persistent postconcussion symptoms (PPCS) is controversial, and there is ongoing debate as to whether the etiology of PPCS is psychogenic or physiogenic. In addition, there is a lack of agreement on diagnostic definitions of mild traumatic brain injury (mTBI) and concussion and the terms are used interchangeably in the research literature. This can lead to confusion and make comparison of research findings on PPCS difficult. Having knowledge of factors related to PPCS can help inform school psychologists as they make decisions about students in the educational setting who report experiencing PPCS. This review will cover the definitions of mTBI and concussion, common postconcussion symptoms (PCS) and PPCS symptomology, and injury and noninjury factors related to PPCS. It will also discuss the implications for the practice of school psychology and list a number of related resources to help school psychologists better understand PPCS.

It is generally well accepted that individuals who sustain a mild traumatic brain injury (mTBI) will experience relatively consistent, short-lived observable signs (e.g., muscle contractions and rigidity, difficulty with eye tracking; Bigler, 2012). As these signs begin to subside, some individuals will go on to report somatic, cognitive, and affective symptoms known as postconcussion symptoms (PCS; Bigler, 2012; Toledo et al., 2012; Yeates, 2010). PCS fall within six domains: physical and postural, cognitive, emotional, somatic, behavioral, and sleep (Toledo et al., 2012; Yeates, 2010). For most individuals, PCS spontaneously resolve within 3 months. However, there are those who will continue to report symptoms for up to a year postinjury (Cassidy et al., 2014; Dean & Sterr, 2013; Mott, McConnon, & Rieger, 2012; Ruff, 2005; Yang et al., 2014). When PCS persist beyond 3 months, they are often referred to as persistent postconcussion symptoms (PPCS). When present, PPCS are generally vague and subjective, measured by self-report, not restricted to those sustaining an mTBI, and in some cases linked to malingering or medicolegal compensation (i.e., workers' compensation, personal injury, automobile accident claims). Therefore, the existence of PPCS is subject to ongoing controversy (McNalley et al., 2013; Reddy, 2011; Yang et al., 2014). Although there is recent neuroimaging evidence of structural damage to the brain in a minority of individuals with PPCS, it has not been established that this damage constitutes a physiological basis for PPCS (Bigler, 2013).

Complicating the issue of PPCS in children is the role of physiological development (e.g., poorly developed cervical musculature) and ongoing brain development (Davis & Purcell, 2014; Pinto, Meoded, Poretti, Tekes, & Huisman, 2012). That is, in relation to body size, children's heads are larger than adults, supporting neck musculature is weaker, and stability at the junction of the skull and neck is more dependent on ligaments than bones. In addition, their brains have less myelinated white matter than adults making children's brains less dense and softer. Combined, these features make

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children more vulnerable to brain injury from the same impact force, which significantly increases the recovery time following mTBI (Davis & Purcell, 2014). It also suggests children require unique diagnosis, assessment, and management following a head injury (McKinlay, Ligteringen, & Than, 2014; Toledo et al., 2012).

In the research literature examining mTBI and concussion the terms *mTBI* and *concussion* are often used interchangeably and there is no single definition for mTBI or concussion. Collectively, this can affect the interpretability of research literature, lead to confusion, and complicate the identification and diagnosis of mTBI and concussion (Yeates, 2010). These inconsistencies also make discussion about injury outcome (including PPCS) challenging. For consistency and the sake of simplicity, this review will use *mTBI/concussion* rather than the single use of either term, with the exception of discussing research specific to one term or the other.

A working knowledge of factors related to PPCS can help inform decisions school psychologists make about students in the educational setting who report experiencing PPCS. Therefore, this review will cover definitions of traumatic brain injury (TBI) and concussion, common PCS and PPCS symptomology, and injury and noninjury factors related to PPCS. It will also discuss the implications for school psychologists and list a number of related resources to help school psychologists better understand PPCS.

DEFINITION OF THE TERMS MTBI AND CONCUSSION

The terms mTBI and concussion are ubiquitous in the research literature on TBI, PCS, and PPCS. Unfortunately, there is ongoing debate as to whether or not a concussion and an mTBI are two separate injuries or if concussion is a less severe form of mTBI (Anderson, Heitger, & Macleod, 2006; Bigler, 2012, 2013; Bodin, Yeates, & Klamar, 2012; Bruns & Jagoda, 2009; Hamilton & Keller, 2010; Kennedy et al., 2006; Lee, 2007; McCrory et al., 2013; Rabinowitz, Li, & Levin, 2014; Uhl, Rosenbaum, Czajka, Mulligan, & King, 2013; Vagnozzi et al., 2010; Zemek, Osmond, & Barrowman, 2013). As a result, there is no single definition or set of diagnostic criteria for either term. Relatedly, disagreement about what constitutes an mTBI or concussion and how these are defined is not limited to research literature and books on brain injury. There are many reputable Internet sites that also contain differing opinions about the interchangeability of mTBI and concussion (McKinlay, Bishop, & McLellan, 2011). In addition, recent studies of the public's understanding of the differences have indicated general confusion and misunderstanding (DeMatteo et al., 2010; Gordon, Dooley, Fitzpatrick, Wren, & Wood, 2010; Mackenzie & McMillan, 2005; McKinlay et al., 2011). Until such time that a unifying definition is developed or specific diagnostic distinctions are established, it is important to be familiar with the current definitions of mTBI and concussion.

MTBI

It is widely recognized that TBI exists across a broad continuum of injury severity that includes mild, moderate, and severe classifications. Unlike moderate and severe TBI, however, there is no universally accepted diagnostic criteria or definition of mTBI, and significant variation exists for inclusion and exclusion criteria across research studies and professional organizations (Bigler, 2012; Bodin et al., 2012; Yeates, 2010). Globally, one of three definitions developed by professional organizations is commonly used to define and diagnose mTBI: (a) the American Academy of Pediatrics (1999) definition, (b) the Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine (1993) definition, or (c) the World Health Organization Collaborating Center Task Force on Mild Traumatic Brain Injury definition (Carroll, Cassidy, Holm, Kraus, & Coronado, 2004). These definitions were developed primarily by medical professionals and although comparable, these definitions provide differing criteria across five diagnostic areas: loss of consciousness, posttraumatic amnesia, Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974), mental status, and neurological signs (Bodin et al., 2012). These criteria are summarized in Table 1. For an in-depth

Table 1. Organization Definitions of mTBI by Diagnostic Area

Diagnostic Area	Organization		
	AAP	ACRM	WHO
LOC	≤1 minute	≤30 minutes	≤30 minutes
PTA	No specification	≤24 hours	≤24 hours
GCS score	No GCS requirement	Does not exceed initial GCS score of 13–15 after 30 minutes	GCS score of 13–15 after 30 minutes postinjury or later upon presentation for healthcare
Mental status	Normal mental status at the initial examination	Any alteration in mental state at the time of the accident (e.g., feeling dazed, disoriented, or confused)	Confusion and disorientation
Neurological deficits	None at exam, but 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	Focal neurological deficit(s) that may or may not be transient	Transient neurological abnormalities such as focal signs, seizure

Note. AAP, American Academy of Pediatrics; ACRM, The American Congress of Rehabilitation Medicine; GCS, Glasgow Coma Scale; LOC, loss of consciousness; PTA, posttraumatic amnesia; WHO, World Health Organization Collaborating Center Task Force on Mild Traumatic Brain Injury.
Adapted from "Definition and Classification of Concussion," by D. Bodin, K. O. Yeates, and K. Klamar. In *Pediatric and Adolescent Concussion: Diagnosis, Management and Outcomes*, edited by J. N. Apps & K. D. Walter, 2012, New York, NY: Springer Verlag. Copyright 2012 by Springer Science+Business Media.

discussion on mTBI and diagnostic considerations regarding these five areas, as well as exclusionary criteria, see Ruff (2005) and Ruff et al. (2009).

There are some researchers (e.g., Bigler et al., 2015; Iverson & Lang, 2011; Iverson et al., 2012; Kennedy et al., 2006; Larabee & Rohling, 2013; Maestas et al., 2014) who further define mTBI as being complicated or uncomplicated based on the presence or absence of visible day-of-injury (DOI) intracranial pathology and an accompanying GCS of 13–15. Individuals who have positive findings on DOI CT scans (i.e., visible evidence of intracranial damage) are considered to have a complicated mTBI (cmTBI), and those with negative findings are considered to have an uncomplicated mTBI. When intracranial damage is present on a DOI CT scan it can include, but not be limited to, skull fracture, hemorrhaging (bleeding), contusion (bruising), hematoma (blood clotting), and edema (swelling; Bigler et al., 2015; Iverson et al., 2012; Stiell et al., 2010). It has been reported that of the roughly 20% of children with cmTBI consisting of a intracranial hemorrhage identified on DOI CT, as many as 3% will require neurosurgical intervention (Hamilton & Keller, 2010; Wang, Griffith, Sterling, McComb, & Levy, 2000).

CONCUSSION

Although there is ongoing debate about whether or not a concussion and an mTBI are two separate injuries or if concussion is a less severe form of mTBI, just like mTBI, different definitions of concussion exist (see below). Additionally, as Bodin et al. (2012) and Jeter et al. (2013) point out, the term concussion is starting to be used more frequently in conjunction with sports medicine research or when referring to a head injury that only produces transient neurological deficits. They further note that the term mTBI tends to be used by other medical specialties (e.g., neurology, neurosurgery) when examining longer lasting pathophysiological (structural) abnormalities. Despite the lack of a universally agreed upon definition of concussion, one commonality is that current definitions do not include a severity classification system. Although grading the severity of concussions has fallen out of favor, a recent meta-analysis quantifying injury characteristics suggests there may be a need to reconsider this practice (Dougan, Horswill, & Geffen, 2014). As seen below, concussion definitions related to sports or sports-specific research are readily available and well articulated while nonsports-specific concussion research definitions tend to be study specific and more nebulously defined.

Concussion is a common occurrence in organized and recreational sports and accounts for approximately 50% of all emergency department concussion visits in children aged 8–19 (Bakhos, Lockhart, Myers, & Linakis, 2010; Caine, Purcell, & Maffulli, 2014; Ling, Hardy, & Zetterberg, 2015). Table 2 summarizes five frequently used sports-related position or consensus statements that define concussion. While these statements have similarities, there are also differences. For example, even though each of these statements provides a definition of concussion and agree that a concussion can occur in the absence of a loss of consciousness, there are differing opinions regarding the biomechanics of injury.

The American Academy of Neurology (AAN), an association composed of neurologists and neuroscience professionals, has defined a concussion as "a clinical syndrome of biomechanically induced alteration of brain function, typically affecting memory and orientation, which may involve loss of consciousness" (Giza et al., 2013, p. 2250). This definition is the basis for the AAN's evidence-based guidelines for evaluating and managing athletes with concussion. The definition is endorsed by the following associations: the National Football League Players Association, the American Football Coaches Association, the Child Neurology Society, the National Association of Emergency Medical Service Physicians, the National Academy of Neuropsychology, the National Athletic Trainers Association, the Neurocritical Care Society, and the National Association of School Psychologists. Although the AAN definition of concussion is likely the most widely endorsed sports concussion definition, this does not confirm the definition's accuracy. It only denotes its popularity.

Definitions of concussion used in nonsports research literature vary depending on the population or sample being studied. In some types of studies, specific definitions for concussion are not given. Participant inclusion is determined based on a participant's referral to/from a hospital's concussion clinic (e.g., Seiger, Goldwater, & Deibert, 2014) or referral from a physician, athletic trainer, or patient previously treated by the researchers (e.g., Lee & Fine, 2010). Typically, in these types of studies the concussion definition and/or diagnostic procedure used by the referral source is not stated. Additionally, it is not stated whether or not concussion was considered by the referent to be synonymous with mTBI. Thus, a study sample can be inclusive of a mix of those with more severe injuries (e.g., depressed skull fracture) and those with less severe injuries (i.e., no visible neuroimaging pathology). When definitions are used with sports-related population samples or combined sports-related and nonsports-related samples, one of the definitions in Table 2 will typically be used to guide sample selection (e.g., Bartnik-Olson et al., 2014; Mayr et al., 2014). Researchers (e.g., Zemek et al., 2013) can also screen participants using an existing definition of concussion and then further limit participants through the use of additional exclusionary criteria (e.g., excluding those with abnormalities on neuroimaging, intoxication at time of injury).

Table 2. Comparison of Concussion Definitions and Characteristics

Characteristic	Organization				
	TPCS	ICSCS	NATA	AMSSM	AAN
Reference audience	Sports athletes	Sports athletes	Sports athletes	Sports athletes	Sports athletes
Definition	Concussion or mTBI is a pathophysiological process affecting the brain, induced by direct or indirect biomechanical forces	Concussion is a brain injury and is defined as a complex pathophysiological process affecting the brain, induced by biomechanical forces	Concussion is defined as a trauma-induced alteration in mental status that may or may not involve loss of consciousness	Concussion is defined as a traumatically induced transient disturbance of brain function and involves a complex pathophysiological process	Concussion is recognized as a clinical syndrome of biomechanically induced alteration of brain function, typically affecting memory and orientation, which may involve loss of consciousness
Biomechanics of injury	Linear and rotational accelerations to the brain	Direct blow to head, face, neck, or elsewhere on the body with an impulsive force transmitted to the head	Forces applied directly or indirectly to the skull that result in rapid acceleration and deceleration of the brain	Linear and/or rotational forces transmitted to the brain	Unspecified
mTBI and concussion	Synonymous. "Concussion or mild traumatic brain injury (MTBI) is a …"[a]	Separate condition. "Concussion is a subset of TBI …"[b]	Synonymous. "When athletes, parents, coaches, administrators, and others discuss concussive injuries, they should use the appropriate medical terminology: concussion or mild traumatic brain injury."[c]	Concussion is a subset of mTBI. "… all concussions are mTBIs, not all mTBIs are concussions."[d]	Synonymous. "… distinctions between concussion and … mTBI are not well established … concussion may be included in this categorization [mTBI] (p. 52) … both terms represent the less-severe end of the … TBI spectrum."[e]

Continued

Table 2. Continued

Characteristic	Organization				
	TPCS	ICSCS	NATA	AMSSM	AAN
Long-term consequences	Acknowledged (>3 months)	Acknowledged (>10 days)	Uncommitted (Defers to research)	Acknowledged (>10 days to years)	Not specified
Loss of consciousness	Not required; when present duration does not predict severity; duration (>1 min.) associated with length of recovery from symptoms	Not required; Duration >1 min. modifies postconcussion management	Not required; Duration >1 min. modifies postconcussion management	Not required	Not required
Signs and symptoms	Short lived with spontaneous recovery; may be delayed onset (unspecified length of delay); total number, intensity, and duration determines severity and is associated with length of recovery	Short lived with spontaneous recovery; may be longer duration and recovery for child or adolescent; may have delayed onset (minutes to hours); symptom severity (>10 days duration) determines management; graded set of clinical symptoms; resolution of the clinical and cognitive symptoms typically follows a sequential course	Short lived with spontaneous recovery	Short-lived; generally self-limited in duration and resolution; number, severity, and duration predict prolonged recovery	Not specified

Continued

Table 2. Continued

Characteristic	Organization				
	TPCS	ICSCS	NATA	AMSSM	AAN
Sign and symptom domains	Cognitive, somatic, affective signs, sleep disturbance	Physical signs, cognitive impairment, neurobehavioral features and sleep disturbance	Not specific; defers to research	Somatic, cognitive, psychological, sleep disturbance	Not specific; defers to research
Severity classification system	None	None	None	None	None
Neuroimaging	Unremarkable	Unremarkable	Defers to research	Unremarkable	Unremarkable

Note. AAN, Evidence-Based Guideline Update: Evaluation and Management of Concussion in Sports; AMSSM, American Medical Society for Sports Medicine position statement: Concussion in sport; ICSCS, Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012; NATA, National Athletic Trainers' Association position statement; TPCS, Team Physician Consensus Statement.
[a]Herring, Cantu, Guskiewicz, Putukian, and Kibler (2011, p. 2412); [b]McCrory et al. (2013, p. 1); [c]Broglio et al. (2014, p. 248); [d]Harmon et al. (2013, pp. 2–3); [e]Giza et al. (2013, p. 8).

Table 3. Common Postconcussion Symptoms

Characteristic	Acute Onset	Delayed Onset
Physical/postural	Alteration/loss of consciousness (dazed, stunned, vacant expression); dizziness/vertigo; nausea/vomiting; tonic posturing; convulsive movements	Dizziness/light headedness/vertigo; visual disturbances ("seeing stars," double vision); difficulty focusing eyes; eye-tracking abnormalities; auditory disturbance (ringing in ears); fatigue; posttraumatic seizures
Behavioral	Inappropriate behavior; difficulties with coordination; difficulties with balance	Intolerance of/sensitivity to light; intolerance of/sensitivity to loud noises; irritability/low frustration tolerance; repeated questioning
Cognitive	Slowed reactions; slurred speech; confusion	Confusion/disorientation; poor attention/concentration; memory problems (anterograde/retrograde amnesia); slow response to questions/reaction times; reduced planning/mental tracking/flexibility; reduced verbal fluency; reduced visual-motor speed/accuracy
Somatic		Persistent/low grade headache; numbness/tingling
Emotional		Anxiety/depression; anxiety/nervousness/depressed mood/sadness
Sleep		Sleep disturbance (drowsiness, hypersomnia, more/less sleep than usual, difficulty falling asleep)

PCS

It is well accepted that following an mTBI/concussion there are relatively consistent, short-lived, observable signs. These signs generally include alteration or loss of consciousness, difficulties with coordination and motor instability, tonic posturing (muscle contractions and rigidity) and/or clonic movements (alternating involuntary muscular contraction and relaxation), and difficulty with eye tracking (Bigler, 2012). As these signs begin to subside, some individuals will begin to experience variable, vague, and ill-defined somatic, cognitive, and affective symptoms usually referred to as PCS (Bigler, 2012; Toledo et al., 2012; Yeates, 2010). PCS have an acute or delayed onset and can fall within six domains: somatic, emotional, physical, behavioral, cognitive, and sleep (Toledo et al., 2012; Yeates, 2010). Although it is not all inclusive, Table 3 provides a summary of common signs and symptoms by domain. Generally speaking, for the majority of individuals, most PCS spontaneously resolve within minutes to hours to days postinjury (Bigler, 2012; McKinlay et al., 2014) with complete resolution within 3 months (Yang et al., 2014).

PPCS

A portion of individuals sustaining an mTBI/concussion (up to 36%) will continue to report vague, ill-defined symptoms of neurocognitive, neurobehavioral, and neurophysiological deficits beyond 3 months postinjury (Cassidy et al., 2014; Dean & Sterr, 2013; Kirkwood, Peterson, Connery, Baker, & Grubenhoff, 2014; Mott et al., 2012; Ruff, 2005; Yang et al., 2014). For these individuals, PPCS are generally reported as somatic, cognitive, behavioral, emotional/affective, and sleep complaints (Kirkwood et al., 2014; McNally et al., 2013; Reddy, 2011; Shenton et al., 2013; Yang et al., 2014; Yeates, 2010). These complaints can include, but are not limited to, headaches, blurred or double vision, dizziness, vomiting, cognitive fatigue, nausea, loss of energy, anxiety, depression, irritability, insomnia, hypersensitivity to light and noise, psychomotor slowing, tinnitus, and sleep disturbances. These can also include difficulties with attention, concentration, processing speed, disinhibition, decision making, and memory.

The etiology of PPCS is the subject of ongoing debate. As Bigler (2013) points out, the controversy concerning the origin of PPCS is not new and it has raged for almost 150 years without being resolved. He also notes that the current debate surrounding mTBI/concussion symptomology is not if there are acute alterations in brain functioning following mTBI/concussion. This has been unequivocally demonstrated. Rather, the controversy is if mTBI/concussion is responsible for causing persistent neurocognitive and neurobehavioral symptoms beyond 3 months. Stated differently, the controversy is whether PPCS are the result of noninjury-related factors or pathophysiological deficits. Each of these viewpoints are briefly summarized next.

Noninjury Factors

On one side of the controversy is the argument that PPCS are the result of noninjury factors. As noted, PPCS symptoms are typically reported to fall within somatic, cognitive, behavioral, emotional/affective, and sleep domains. However, the report of difficulties in these domains is not restricted to those individuals sustaining an mTBI/concussion (Cassidy et al., 2014; Clarke, Genat, & Anderson, 2012; Iverson & Lange, 2003; Kirkwood et al., 2014; Larrabee & Rohling, 2013; Smith-Seemiller, Fow, Kant, & Franzen, 2003). For example, these symptoms have been found to be present in individuals with depression, posttraumatic stress, and anxiety (Cassidy et al., 2014). Furthermore, it has been suggested that those reporting PPCS may be inaccurately recalling the number of premorbid symptoms, erroneously perceiving there has been an increase in symptoms post injury, and misattributing the apparent increase to the injury (Brooks et al., 2014; Yang et al., 2014). In other words, symptoms reported as persisting beyond 3 months may be symptoms that were present prior to the injury.

Pathophysiological Deficits

Opposing the viewpoint that noninjury variables are responsible for PPCS is the position that PPCS are the result of pathophysiological deficits incurred as a result of injury to the brain. Those in support of the nonpathophysiological view often turn to a lack of positive neuroimaging findings on the DOI CT or anatomical MRI scans (e.g., T1-weighted) as indicating that injury to the brain has not occurred; ergo, PPCS must be the result of other factors. However, proponents of the pathophysiological view argue that CT and conventional MRI (e.g., T1-weighted) methods are not sensitive to the more subtle chronic pathologies responsible for producing PPCS (Bigler, 2013; Bouix et al., 2013; Shenton et al., 2013).

IMPLICATIONS FOR SCHOOL PSYCHOLOGISTS

It is clear that a variety of complex, interrelated factors are associated with PPCS. Although there is debate among researchers regarding these factors, up to 36% of individuals who sustain an mTBI/concussion will go on to report experiencing PPCS (Cassidy et al., 2014; Dean & Sterr, 2013; Kirkwood, et al., 2014; Mott et al., 2012; Ruff, 2005; Yang et al., 2014). Currently, there is no way to predict which students who return to school after sustaining an mTBI/concussion will go on to report experiencing PPCS. Therefore, school psychologists will need to monitor student progress and make referrals to the appropriate range of services when necessary. Unfortunately, there are no guidelines for school psychologists regarding monitoring students for the emergence of PPCS or for providing academic interventions to students who report experiencing PPCS. The following sections provides some possible guidelines and discusses implications for assessment of PPCS.

Monitoring and Referral to Specialists

The expression/manifestation of PPCS is highly variable, unique to the individual, and the symptom course is unpredictable. In addition, when exactly PCS becomes PPCS is unknown and highly debated by researchers and medical professionals. Therefore, it is important that when school psychologists become aware that a student has returned to school following an mTBI/concussion, they should immediately begin to monitor the student's recovery. Monitoring should include frequent contact with the student, the student's parents, and the student's teacher(s) to assess any perceived or reported changes in the student's level of neurological, social, and behavioral functioning. Collected data should be recorded and comparisons should be made to preinjury baseline data or estimates. These data should be given to the student's parents and the parents should be encouraged to share it with any medical professional involved in the student's care. Alternatively, with appropriate parental consent, a school psychologist can be the designated individual who shares the data with medical professionals. Monitoring should continue until such time that PPCS resolve. Although the best time to refer a student who reports experiencing PPCS to a specialist is not known (Marshall, Bayley, McCullagh, Velikonja, & Berrigan, 2012), Halstead et al. (2013) recommend that individuals with PCS lasting greater than 3 weeks be referred to a licensed specialist with knowledge and experience in the management of concussion (e.g., pediatrician, neurologist, primary care sports medicine specialist, neurosurgeon). In addition to monitoring a student's recovery for the emergence of PPCS following an mTBI/concussion, school psychologists should consider possible school-based interventions as indicated below.

Section 504 of the Rehabilitation Act of 1973 and Individuals With Disabilities Education Improvement Act of 2004

Marshall et al. (2012) have noted that the best time to deliver interventions and conduct follow-up assessment for individuals who have sustained an mTBI/concussion is unknown. Likewise the best time to deliver interventions to students with PPCS is largely speculative. However, two existing federal laws provide school psychologists with possible avenues for addressing these issues: the Individuals with Disabilities Education Improvement Act of 2004 (IDEIA 04) and Section 504 of the Rehabilitation Act of 1973 (Section 504). Halstead et al. (2013) suggest a reasonable three-tiered approach to the implementation of Section 504 and IDEIA 04 services for students who have sustained a concussion: academic adjustment, academic accommodation (Section 504), and academic modification (IDEIA 04). They do caution, however, that this approach should be appropriately flexible to allow for the unique variability and severity of symptom constellations. In this approach, the academic adjustment tier begins during the first 1–3 weeks following an mTBI/concussion and includes providing nonformailized minimal support to the student through academic environmental adjustments that do not require changes in standardized testing or curriculum. These adjustments are aimed at minimizing the chance of worsening a student's physiological symptoms. Halstead et al. (2013) do not describe what adjustments should be made at this tier. However, in a related article by Halstead, Walter, and Counsel on Sports Medicine and Fitness (2010) it is suggested that such things as shortening the student's day, reducing workloads, and extending deadlines may help to prevent exacerbation of symptoms. Halstead et al. (2013) also recommend that parents be encouraged to check with the student and school personnel to ensure that the adjustments are being implemented.

The academic accommodation tier begins when PCS persist beyond 3 weeks and includes accommodations for standardized testing, allowing extra time for classwork and assignments, and class schedule changes. Halstead et al. (2013) suggest this would be the appropriate point to implement a formalized Section 504 accommodation plan. The academic modification tier begins when there is a need for more significant changes in the student's educational plan and involves the implementation of IDEIA 04 services. Halstead et al. (2013) suggest this tier be implemented when PCS persist beyond 5–6 months, making this tier an appropriate intervention for students experiencing PPCS. They also recommend that at the academic accommodation and academic modification tiers that the student's medical team, school multidisciplinary team, and family work together to develop appropriate interventions and educational goals to be formalized in an Individualized Education Plan (IEP) and/or Section 504 plan. In addition to the interventions mentioned by Halstead et al. (2013) and those formalized through an IEP and/or Section 504 plan, some school psychologists might consider using interventions that have been developed to target common short-lived PCS with students who are experiencing PPCS. This possibility is discussed next.

Using PCS Interventions

Resources are available that suggest a variety of educationally focused interventions designed to target students who return to school following an mTBI/concussion (see Additional Resources section below; Halstead et al., 2013; Sady, Vaughn, & Gioia, 2011). Unfortunately, these interventions primarily focus on common short-lived PCS and are based on professional opinion (e.g., cognitive rest) or logic (e.g., if bothered by light, allow the student to wear sunglasses). Additionally, they lack sufficiently strong evidence-based research support regarding their efficacy (Halstead et al., 2013; McCrory et al., 2013). One major limitation of these recommended interventions is that they are often written in an ambiguous manner. Examples include limiting cognitive activities that require a student to "think harder than usual" (Brown et al., 2014, p. e301) and limiting "exertion with activities of daily living that may exacerbate symptoms" (McCrory et al., 2013, p. e6). These two interventions fall under a popular intervention known as cognitive rest. Other cognitive rest interventions include, among other things, limiting the student's opportunity to engage in activities such as homework, video gaming, and watching TV. It is important to note that despite the popularity of cognitive rest following an mTBI/concussion, recent research on the benefit of cognitive rest is mixed (Brown et al., 2014; Gibson, Nigrovic, O'Brien, & Meehan, 2013). While it is tempting to implement interventions that are designed for short-lived PCS (e.g., cognitive rest) with students experiencing PPCS, this practice should be approached with caution as there is no research-based evidence to indicate the generalizability of PCS interventions to those who report experiencing PPCS. When considering whether or not to implement PCS interventions with students who report experiencing PPCS, school psychologists should always consult with the student's attending medical professional(s) and parents before making these recommendations into a formal intervention. They should also be diligent about frequently monitoring the efficacy of these interventions once they are implemented.

Developing appropriate interventions for students experiencing PPCS will depend, in part, on establishing that the symptoms are actually a result of an mTBI/concussion. There are three factors that can complicate the assessment of PPCS: coexisting injuries, the self-report of PPCS, and medical discharge records. These are discussed next.

Coexisting Injuries

Marshall et al. (2012) note that an mTBI/concussion can be sustained in a way that results in multiple injuries or substantial emotional reactions (e.g., falls, automobile accidents). For example, as a result of an automobile-pedestrian accident, a child could conceivably receive an mTBI/concussion and compound fractures to the fibula and femur. During the days/weeks that follow, the child could undergo multiple surgeries to repair the broken fibula and femur. Four months later, while still recovering from the surgeries, the child may begin reporting headaches, dizziness, anxiety, and attention and concentration deficits, and complain of slowed processing speed, fatigue, loss of energy, memory impairments, and irritability. At this point, determining if the child is experiencing PPCS, depression, or both may be difficult. Furthermore, establishing the etiology may be even more complicated and require the assistance of licensed specialists who have knowledge and experience in the management of mTBI/concussion (e.g., primary care sports medicine specialist) and the child's attending medical professionals (e.g., pediatrician, neurologist, neurosurgeon).

How coexisting, nonbrain injury factors contribute to recovery following an mTBI/concussion, or how the factors contribute to the development of PPCS, is not known. In addition, this relationship has received little attention in the research literature (Marshall et al., 2012). Although a school psychologist and multidisciplinary team may have little difficulty establishing there has been a resulting educational impact, in order to attribute the cause to the mTBI/concussion the school psychologist may need to consult with knowledgeable others (e.g., neurologists).

Self-Report of PPCS

As noted previously, PPCS are vague, ill-defined symptoms of neurocognitive, neurobehavioral, and neurophysiological deficits reported by the individual. Results from a recent study by Kirkwood et al. (2014) suggested that 12% of the 191 participants between the age of 8 and 17 who sustained an mTBI/concussion may have been exaggerating or feigning PPCS symptoms. Much of the information school psychologists obtain during typical psychoeducational assessments of students in educational settings across the United States is based on assumptions that students are presenting accurate representations of ability, effort, and motivation. It is also assumed that measured signs and reported symptoms are accurate and honestly reported. The same safeguards school psychologists implement as best practice in the psychoeducational assessment of students apply to the assessment of PPCS reported by students following mTBI/concussion. For those students who are suspected of exaggerating or feigning PPCS symptoms, Kirkwood et al. (2014) suggest that neuropsychologists and pediatric neuropsychologists may be helpful in establishing the validity of reported PPCS. School psychologists may also find that conducting a school-based functional behavioral assessment (see Watson & Steege, 2003) is helpful in determining validity of reported PPCS.

Children age 3–5 have limited verbal ability to describe emotions (McConaughy, 2005) and therefore may not be able to adequately report PPCS. In cases where a school psychologist is involved in the assessment of a preschool child who has sustained an mTBI/concussion, the school psychologist should consult with parents to establish any changes in behaviors that might be attributable to PPCS. The school psychologist should also consult with pediatric neurologists and be familiar with the nuances involved in interviewing children in this age group. Three resources specific to the clinical interviewing of children that can aid the school psychologist when interviewing younger students about vague, ill-defined PPCS are listed below in the Additional Resources section. Relatedly, it is important to understand that young brains have less myelinated white matter than adults making children's brains less dense and softer. Thus, young children are more vulnerable to brain injury from the same impact force. It can also significantly increase the recovery time following mTBI/concussion (Davis & Purcell, 2014; Pinto et al., 2012) and suggests children require unique diagnosis, assessment, and management following a head injury (McKinlay et al., 2014; Toledo et al., 2012). By consulting with pediatric neurologists, a school psychologist can better understand that course of recovery following pediatric mTBI/concussion and clarify if a young child is experiencing PPCS.

Medical Discharge Records

While discharge records from emergency departments and doctors' offices can be informative, they are not always necessarily definitive. For example, a recent retrospective study of 218 children between 6 and 18 who met the Third International Conference on Concussion in Sport diagnostic criteria for concussion (McCrory et al., 2009) found that the majority of these children had been treated and released from a level 1 trauma center emergency department in 2008 without a concussion-specific diagnosis or any activity restrictions (De Maio et al., 2014). Therefore, school psychologists should not assume that a student is unimpaired because he or she has failed to receive a medical diagnosis of mTBI/concussion following a blow to the head or that a student's reported PPCS are not related to an mTBI/concussion. Instead, as a precaution, whenever a student is known to have received a significant blow to the head, school psychologists should work with parents, teachers, and medical professionals to implement the minimal nonformailized academic adjustments suggested by Halstead et al. (2013). The student should then be monitored for PCS and if the symptoms persist beyond 3 weeks, school psychologists should refer the family to a licensed specialist with knowledge and experience in the management of mTBI/ concussion as suggested by Halstead et al. (2013). School psychologists should then consider more intense interventions (e.g., Halstead et al.'s Tier 2 and 3 interventions).

Finally, the relationship between mTBI/concussion and the contact sport of American football has received a great deal of popular media coverage in the United States during the past 10–15 years. Although it is not the only contact sport to be covered by the popular media, nor is it the only sport (contact or noncontact) in which a mTBI/concussion can occur (see Centers for Disease Control and Prevention, 2011), it is likely the most heavily researched contact sport. Therefore, football will be briefly addressed next.

Football

Each year in the United States, approximately 4.8 million children ages 6–18 years of age will play contact football accounting for approximately 50% of all organized team sport concussions (Young, Daniel, Rowson, & Duma, 2013). This warrants a brief review of research using accelerometer arrays inside of football helmets to measure impact forces to the head during practice and play. A recent review of this literature by Broglio, Eckner, and Kutcher (2012) found that the average high school football athlete received more than 650 impacts in a single season. It also found that the biomechanical threshold for concussion was approximately 100 g of linear acceleration and 5500 rad/s/s of rotational acceleration. There are a limited number of impact studies conducted on children below high school age, however, Daniel, Rowson, and Duma (2014) found that in a sample of 17 children ages 12–14, the average number of helmet impacts during a season was 275 with linear accelerations ranging from 10 to 149 g, and the rotational accelerations ranged from 2 to 8235 rad/s^2. A study of 50 children between the age of 9 and 12 found the average number of helmet impacts during a season was 240 with linear accelerations ranging from 10 to 126 g, and the rotational accelerations ranged from 4 to 5838 rad/s^2 (Cobb et al., 2013). In a similar study of a small sample of children between the ages of 7 and 8 ($N = 7$), Daniel, Rowson, and Duma, (2012) found the average number of helmet impacts during a season was 107 with linear accelerations ranging from 10 to 100 g, and the rotational accelerations ranged from 52 to 7694 rad/s^2. These studies all indicate that impacts occur at all ages sufficient enough to cause a concussion as well as impacts at the subconcussive level.

School psychologists should continue to follow this line of research and share the results with students, parents, and athletic coaches when appropriate. Additionally, school psychologists should work to educate school district administrators, building administrators, teachers, athletic coaches/trainers, and parents about PPCS. They should also help develop a district-wide mTBI/concussion intervention plan. This plan should include the ongoing monitoring of all students who have sustained a sports- or nonsports-related mTBI/concussion. Ongoing monitoring, as described above, should occur for a minimum of 4–6 months (preferably 12 months) in order to make sure PPCS are not being reported by the student or knowledgeable others.

CONCLUSION

Fully understanding the long- and short-term consequences of a mild insult to the brain remains challenging. Debate, inconsistent definitions, and the interchangeable use of terminology make it difficult to develop a well-defined clinical picture of what it means to have sustained an mTBI/concussion. Consequently, it is not surprising there are conflicting opinions about symptom etiology and how long neurological symptoms should persist following an mTBI/concussion. Regardless of current debates, a portion of individuals will continue to report experiencing neurological symptoms up to a year following an mTBI/concussion (Dean & Sterr, 2013; Mott et al., 2012; Ruff, 2005; Yang et al., 2014). As MRI and other forms of neuroimaging evolve, more will be learned about the acute and chronic structural and pathophysiological consequences of mTBI/concussion and a better understanding of PPCS will emerge. For the time being, however, in order to make informed decisions about children who report experiencing PPCS after sustaining an mTBI/concussion, school psychologists will need to rely on the available mTBI/concussion research literature and, as Halstead et al. (2013) recommend, consult with licensed specialists with knowledge and experience in the management of mTBI/concussion.

There are treatment recommendations available for students experiencing short-lived PCS that could be implemented for students who report experiencing PPCS. At the current time, however, these appear to be grounded in professional opinion and logic, and not strongly supported by evidence-based research. Therefore, the efficacy of these interventions is not known. Additionally, the generalizability of PCS interventions to students reporting PPCS has not been established nor sufficiently researched. Halstead et al. (2013) recommend a viable three-tiered approach to implementing Section 504 and IDEIA 04 services for students who have sustained an mTBI/concussion. In addition to the continuation of any effective Section 504 accommodations implemented in tier two of this approach, the third tier, academic modification (IDEIA 04), seems best suited to provide any necessary longer term educational supports for students who report experiencing PPCS. Interventions at this level can, and should, be developed with the assistance of licensed neurologists, neuropsychologists, and physicians in cooperation with parents and multidisciplinary school-based teams.

Zemek et al. (2013) are currently conducting a prospective, multicenter cohort study across nine academic Canadian pediatric emergency departments called the Predicting and Preventing Postconcussive Problems in Pediatrics (5P) study (Zemek et al., 2013). The stated purpose of this study is to “derive a clinical prediction rule for the development of persistent postconcussion symptoms in children and adolescents presenting to emergency department following acute head injury” (p. 1). The free source link for more information on this study is listed below. School psychologists should follow this study as information gleaned from this study will likely provide relevant information in the diagnosis and treatment of children with mTBI/concussion who report experiencing PPCS.

As a final note, the perception that an mTBI/concussion is an insignificant event appears to be changing among laypersons and professionals as evidenced by the increased media attention and steadily increasing number of neuroimaging research studies examining mTBI/concussion. It is hoped this trend is real and will continue as it can only help children who have sustained an mTBI/concussion who go on to report PPCS become more successful in the educational setting.

ADDITIONAL RESOURCES

In addition to the resources provided throughout this review and in the reference section, what follows represents additional resources that may assist school psychologists in better understanding mTBI/concussion and PPCS.

Brain Injury in Children and Youth: A Manual for Educators. Retrieved from https://www.cde.state.co.us/sites/default/files/documents/cdesped/download/pdf/tbi_manual_braininjury.pdf

Centers for Disease Control and Prevention Resources

Centers for Disease Control and Prevention (N.D.). Helping Students Recover From a Concussion*: Classroom Tips for Teachers*. Retrieved from http://www.cdc.gov/headsup/schools/teachers.html

Centers for Disease Control and Prevention. (2013). *Acute Concussion Evaluation (ACE) care plans*. Retrieved from http://www.cdc.gov/headsup/providers/discharge-materials.html

Centers for Disease Control and Prevention. (2013). *Concussion: What are the Signs and Symptoms of Concussion?* Retrieved from http://www.cdc.gov/concussion/signs_symptoms.html
Centers for Disease Control and Prevention. (2013). *Growth Charts*. Retrieved from http://www.cdc.gov/growthcharts/
Centers for Disease Control and Prevention. (2013). *Heads Up Concussion: Clinicians Training*. Retrieved from www.cdc.gov/concussion/HeadsUp/clinicians/index.html
Centers for Disease Control and Prevention. (2013). *Heads Up to Healthcare Providers* Retrieved from www.cdc.gov/HeadsUp/providers/index.html
Centers for Disease Control and Prevention. (2013). *Heads Up to Clinicians: Updated Mild Traumatic Brain Injury Guideline for Adults*. Retrieved from www.cdc.gov/concussion/HeadsUp/clinicians_guide.html
Centers for Disease Control and Prevention. (2013). *Injury Prevention & Control: Motor Vehicle Safety: Child passenger safety*. Retrieved from http://www.cdc.gov/Motorvehiclesafety/Child_Passenger_Safety/index.html
Centers for Disease Control and Prevention. (2013). *Injury Prevention & Control: Traumatic Brain Injury*. Retrieved from http://www.cdc.gov/TraumaticBrainInjury/data/index.html
Centers for Disease Control and Prevention. (2013). *Prevention: What Can I Do to Help Prevent Traumatic Brain Injury?* Retrieved from http://www.cdc.gov/traumaticbraininjury/prevention.html

Selected Interviewing Resources Specific to Childhood and Adolescence

Guidelines for Diagnosing and Managing Pediatric Concussion (1st ed.). Ontario Neurotrauma Foundation, 90 Eglinton Street, East Toronto, ON M4P 2Y3; available from http://onf.org/documents/guidelines-for-pediatric-concussion
Predicting and Preventing Postconcussive Problems in Paediatrics (5P) Study: Protocol for a Prospective Multicentre Clinical Prediction Rule Derivation Study in Children With Concussion. Available from http://bmjopen.bmj.com/content/3/8/e003550.long
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Morrison, J., & Anders, T. F. (1999). *Interviewing children and adolescents: Skills and strategies for effective DSM-IV diagnosis*. New York, NY: Guilford Press.
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Bartnik-Olson, B. L., Holshouser, B., Wang, H., Grube, M., Tong, K., Wong, V., & Ashwal, S. (2014). Impaired neurovascular unit function contributes to persistent symptoms after concussion: A pilot study. *Journal of Neurotrauma*, *31*, 1497–1506.
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